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SILICATE SCIENCE*

By George W. Morey

Abstract

An attempt is made to correlate, by means of the changing properties of silica in a crystallizing rock magma, the various branches of science and technology which are concerned with the properties of silicates. Such a discussion serves to bring out both similarities and differences between the processes taking place in nature and those characteristic of the many branches of technology dependent on the properties of silicates.

I. Introduction

The purpose in this address will be to bring out the relationship among the various branches of science and technology which are concerned with the properties of silicates. The chemistry of silica and the silicates is the fundamental basis of ceramic engineering and glass technology; it controls the composition of the slags used in metallurgical operations, and is a dominant consideration in geology as an experimental science. The various applications of silicate chemistry will be discussed, taking the change in composition of the cooling magma as the connecting thread.

II. Rock Magma Transformation

Silica has characteristic properties. Notwithstanding its high melting point, it is exceedingly viscous in the liquid condition. Largely because of that viscosity, it is reluctant to change from the liquid to the crystalline condition. The viscosity and the tendency to form glass are characteristics of silica which are carried, to a greater or less extent, into all the mixtures and compounds into which it enters. The extent to which these characteristics are carried into its compounds depends, in the first place, on the proportion of silica present, and, to a less extent, on the nature of the other constituents.

The manner in which an originally homogeneous silicate melt called a rock magma is transformed into the widely diversified rock types we find in nature, that is, the sequence of crystallization of the silicate minerals which make up the rocks, is a major problem in geology, and the researches of the Geophysical Laboratory of the Carnegie Institution of Washington have been concerned with the crystallization of silicate melts in order to learn the mechanism by which the rock minerals have been formed.

The primitive magma is considered to have been low in silica, and silica-free minerals were among the first to crystallize at the highest temperatures. These include magnetite, which separates over a wide range of conditions, and the spinels, compounds of alumina with the oxides of magnesium, calcium, and iron. The silicate minerals which crystallize early in the process of differentiation, such as olivines, are orthosilicates, which are poor in silica. They are all of high melting point, and recently, since advances in industrial technique have made possible their manufacture, similar materials have found an important use as refractories.

III. Slag Is a Silicate Magma

The magma from which these minerals separate has no counterpart in ceramics, but similar silicate mixtures play an important part in the metallurgy of iron. The crude ore and the fuel used in melting contain impurities, sand and silicate minerals, phosphates, and combined sulfur. These impurities are removed by the fluxing action of a slag, formed by the addition of lime. The slag must be high enough in lime to extract the sulfur and phosphorus, and it must be fluid enough to run readily when tapped, yet viscous enough not to be excessively corrosive to the furnace lining. A slag approaching the orthosilicate composition gives this desirable balance of properties, and blast-furnace slags are of such a composition that the orthosilicate minerals frequently crystallize from them.

The magma, after the crystallization of most of the orthosilicate minerals, is enriched in silica. It has become a basaltic magma such as is found in the volcano Kilauea. The minerals which now begin to separate are the pyroxenes, metasilicates of magnesium, calcium, and iron. In the earlier stages olivines are also present, and in the later stages plagioclase feldspars, containing both lime and soda feldspars, are of increasing importance. Enormous quantities of such magmas have been poured out in fissure eruptions, form-

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ing, for example, the plateau basalts of the northwest, which cover an area of a quarter of a million square miles and reach a maximum thickness of 6000 feet. Such lavas are highly fluid and crystallize readily, and basalt glass is found only in volcanic regions where it has been extruded and chilled rapidly.

The rocks formed from basaltic magmas, the gabbros and trap rocks, find little use in industry except as crushed rock and as building stone. Silicate melts of similar composition are not met with in ceramics, but the slag used in an acid open-hearth steel furnace of the type common a few years ago, in which the bottom is made of silica, is similar in its silica content. Slags of higher silica content would be less corrosive on the silica bottom, but the consequent high viscosity precludes their use.

IV. Obsidian Glass

In the subsequent stages of magmatic differentiation, with temperature continuously decreasing, the ferromagnesian minerals disappear; feldspars increase in amount. The plagioclase feldspars contain more albite, and quartz appears as a primary mineral. On further differentiation, the typical granites, composed of orthoclase and plagioclase feldspar, quartz, and mica, are formed. They are usually well crystallized, but enormous quantities of natural glass of a composition which would form granite if crystallized are found in many parts of the world. A common natural glass of this type is obsidian, and the obsidian cliffs of Yellowstone Park are familiar. Obsidian is easily shaped by flaking, and primitive people in all parts of the world have used it for arrow-heads, spear-heads, and for ceremonial purposes. The Aztecs also used it for razors, and remains of their flake knives are common in the Valley of Mexico. The obsidian was mined at a distance and fashioned into cylinders, three or four inches long, and slightly less in diameter. In this form it was easily transported and was a primitive package of razor blades. When a razor was required it was flaked off by pressure, and the resulting blade was about the most efficient cutting instrument known to man until the invention of steel.

The reason why the natural glass, obsidian, is found in enormous masses is that a liquid composed of quartz and alkali feldspar is exceedingly difficult to crystallize. The soda feldspar, albite, melts at 1120°C, and the potash feldspar, orthoclase, begins to melt at 1170°C. But at 1400°C, the viscosity of their melts is about one million times greater than that of a basaltic magma at the same temperature. This explains why the glassmaker does not imitate nature and make artificial obsidian glass. It would have excellent qualities, but it is impossible to make it artificially because of its great viscosity even at the highest temperatures attainable in modern furnace practice. The feldspars do find an important use in ceramics. By virtue of their low melting point and the high viscosity of the resulting glass, they make excellent glazes, and a refractory body with a feldspar glaze is one of the finest types of porcelain.

V. Rôle of Water in Crystallization of Magma

In nature the granitic rocks crystallize at comparatively low temperature, which means that they persist as liquids to a temperature at which artificial melts of the composition of the final rock, composed, for example, of potash, alumina, and silica in the molecular ratio of 1:1:10, and nothing else, would be so viscous as to be brittle. Nevertheless, the granites are well-crystallized rocks, and in pegmatite deposits orthoclase and quartz are in massive crystals. Such development of crystals would not be possible if it were not for the presence in the magma of other constituents which serve to lower the viscosity, and of these constituents water is the most important. The temperature, while comparatively low, is far above the critical temperature of water, and the water can only be held in the liquid magma by an impervious crust sufficiently strong to withstand the pressure of the water in its attempt to escape as steam. If the crust is not competent, a volcanic eruption results, and the most violent and catastrophic eruptions are those in which the ejected material has essentially the composition of obsidian.

The granites represent the concentration of all the magmatic constituents after separation by crystallization of the ultra-basic and basic minerals, and Bowen has demonstrated how a magma low in silica, as the result of the continuously changing association of crystallizing minerals, will be transformed into a magma high in silica and alkali feldspar. The crystallization of a magma containing these constituents alone, at the comparatively low temperatures we know

must have existed, into the coarsely crystalline rocks we know as granites would have been impossible, and the granites owe their structure to the effect of the other magmatic constituents, especially water, which have accumulated as the result of differentiation.

VI. Decomposition by Water

Important as is the rôle of water in making possible the crystallization of the granites, its effect in decomposing these same rocks is of even greater importance in ceramics. We usually think of rocks and ceramic products as being resistant to water at ordinary temperatures, and so they are. But when the action takes place over long periods, all silicates are decomposed, and the result of the decomposition of granite by water is clay. The clay minerals are a group produced by secondary action, long after the rocks have crystallized and all of them consist essentially of silica, alumina, and water. All the alkali of the feldspar, as well as much of the alumina and silica, has been removed, and the residual clay is the basic raw material of ceramics.

VII. Clay Not Always End-Product of Weathering

Clay is composed not only of the various clay minerals, which may be grouped together under the name kaolin, but it may also contain residual quartz, iron oxide, and various silicate minerals, all in varying amounts. Clay is not always the end-product of weathering, and in the warmer climates even clay is decomposed with formation of more aluminous minerals, bauxite and diaspore. The diaspore clays of Missouri are an example. The uses of clay in ceramics depend chiefly on the amount of the accessory minerals.

VIII. Effect of Heat on Clay

When kaolin is heated it is decomposed, and the usual end-product is a mixture of highly siliceous glass and the mineral, mullite. Pure kaolinite contains two molecules of silica to one of alumina and forms a moderately refractory material. The more impure clays usually contain enough iron oxide to make them red when fired, and when such clays also contain both lime and alkali they become bonded at fairly low temperatures by the formation of a low-melting glass into a structurally strong material, the common brick. The more they approach kaolin in composition the more refractory they are, and the more viscous is the glassy matrix. Because of the viscosity of this glass, the conversion of the decomposed kaolin to the condition of equilibrium below 1545°, a mixture of mullite and crystalline silica, is never complete. The mullite is crystallized only in part, tridymite or cristobalite is often not developed at all, and if quartz has been added to the clay its solution and conversion into glass take place slowly. It is because of these factors that clay is so universally used for materials which must withstand heat, the refractories, and for other useful products for which the development of a glassy bond to unite the unmelted portions into a dense and strong material is essential. Such products range from spark plugs and electrical porcelains to whiteware.

When the clay contains an excess of alumina over the proportions found in kaolin, the temperature required in firing increases, and the resulting product becomes of increasing value as a refractory. Indeed, since the mineral, mullite, was discovered at the Geophysical Laboratory in 1924, the improvement in refractories has been rapid and has constituted one of the most important advances in technology.

IX. Ceramic Ware Properties Dependent on Glass Bond

The presence of a glassy bond is essential in refractories, in brick and tile, in glazes, and in enamels, and all these products are made possible by the ability of silicates to form glass. Generally speaking, the controlling factor in the choice of raw materials is the viscosity essential to the product and its method of manufacture. The composition of slags is largely determined by viscosity. The development of strength in the many types of clay products not used at high temperatures depends on the development of a glass having the requisite viscosity at the temperature of firing, and the higher the temperature required the greater the cost of the operation. Consequently we have a wide range of glass compositions developed, from those enamels containing lead oxide and boric oxide, which lower the temperature of glass formation and enable the products to be made at lower temperature and lower cost, to the finest porcelains, which require firing at high temperatures to liquefy sufficiently the viscous glassy bond. And finally we have the glasses themselves.

X. Silica Glass

I have already mentioned that silica has a high melting point and that at its melting point it is highly viscous. Silica glass can not be manufactured cheaply or on a large scale because of the high temperature required and the extreme viscosity of the melt even at that temperature. Laboratory ware of silica glass is produced by hand-working before the blow-pipe, and even on this small scale the source of the raw material is of the greatest importance. Any ordinary quartz will not do if the finished product is to be clear and free from bubbles. On the contrary, only quartz from special localities, formed under conditions which are still unknown to us, is suitable for the finest grade of silica glass.

One of the first studies of the Geophysical Laboratory was by Day and Shepherd on the production of fused silica, and they devised a process which was later developed commercially. They melted the quartz in vacuum, which greatly increased the size of the bubbles and thus the ease with which they were eliminated. Then when the silica glass was ready to be cooled, pressure was applied, causing the remaining bubbles to shrink to a fraction of their previous size.

Even this process is not entirely successful. It is not merely a problem of heating the silica hot enough to make it a thin liquid. If the temperature is raised much above the melting point, the silica vaporizes; and if any reducing agent is present—and it is difficult to prevent the presence of some carbon, carbon monoxide, or hydrogen—the silica is reduced to silicon. These difficulties usually become more serious as the temperature is raised, and an increase of a few hundred degrees in available furnace temperatures would not make possible the large-scale production of silica glass.

XI. Effect of Composition on Glass Properties

For the manufacture of glass, the melting point and viscosity of silica must be lowered to industrially practicable values, for which purpose recourse must be had to fluxes. We have seen that in the process of firing kaolin a glass is formed composed of alumina and silica, and it might appear that the addition of a flux, such as sodium carbonate, would give a glass that could be manufactured. Such is not the case. The systems containing soda or potash and alumina are unique in their viscosity relationships, in that there appears to be a maximum of viscosity when alkali oxide and alumina are in the 1:1 molecular ratio, as they are in the feldspars. Addition of alkali to a kaolin increases the amount of glass formed by lowering the melting point, but the glass increases in viscosity with addition of soda until the 1:1 ratio is passed. Similar effects are found with other properties, such as density and refractive index, and there appears to be a constitutive effect in the alkali-alumina-silica systems which is unique. It is for this reason that the glassmaker can not imitate nature and make glass of the composition of granite, although the melting point of the granite is at a temperature easily accessible in furnace practice.

Commercial glass is made by the addition of fluxes, especially soda or potash, to silica, and soda is the usual choice, partly because of its lower price. Soda alone will not do, however, even though it is cheap and efficacious, because the resulting glasses are soluble in water. Something must be added to give them the necessary chemical durability, and lime is the usual choice. Other oxides could serve. A soda-magnesia-silica glass can be made, but not so easily as a soda-lime glass, and magnesia is used only with lime. Barium or strontium oxide can be used, and barium oxide is frequently used in special cases, but the greater cost and greater weight of these oxides are sufficient to cause their rejection, except for special types. Lead oxide can be used, but the same objections hold. All other oxides are rejected for chemical or economic reasons, and most glassware is a soda-lime-silica glass.

This has always been true. Probably the oldest piece of glass ever found was the cylinder of light blue glass brought back by the University of Chicago Iraq expedition in 1931 from Tell Asmar, a little northwest of Bagdad, which dated to about 2700 B.C. It had a refractive index of about 1.515, and was surprisingly free from striations or inclusions. The oldest Egyptian glass concerning whose authenticity and dating there is no doubt was the glass beads found in the sarcophagus of little Moyet, child queen of King Mentu-hotpe III, about 2050 B.C. Both the glass from Asia Minor and that from Egypt were of the same type, soda-lime glasses. All the ancient glass was of this type, not differing essentially from the usual glass of today. Typical glassware has always been of the same composition, and the reason is not far to seek. I have

already stated that to make a glass the melting point and viscosity of silica must be lowered by a flux; that the best and most convenient flux, soda, produces a glass easily attacked by water; and that addition of lime is the best and cheapest means to give the necessary chemical durability to the soda-silica glass. But the proportions of these three ingredients are not alterable at will. There is only a narrow range within which these three oxides can be combined to give a glass. Too much soda, and it is not durable. Indeed, most of the ancient glass found in the Egyptian tombs contains too much soda. This made it easier to melt in their primitive furnaces, but the product would be rejected today by any critical user as being lacking in durability. Too much silica, and the glass is too viscous and hard to melt. Too much lime, and it too closely approaches the properties of a basaltic lava, highly fluid and crystallizing readily.

Of the whole range of possible silicate compositions the only mixtures which are fluid enough at an industrially accessible temperature to be melted on a commercial scale, yet viscous enough to be worked at temperatures above their freezing points so that they will not devitrify into products which are not glass, and stable enough toward the action of water to be suitable for the many uses to which glass is put are those soda-lime-silica mixtures which have always been used for glass.

Silica, crystallized as quartz, is one of the commonest minerals of the earth's crust, yet its high melting point and the great viscosity of molten silica are of little importance in nature. The magmas crystallizing at the highest temperatures are those poorest in silica, and not until extensive differentiation has taken place is crystalline silica an original rock constituent. Silica and the minerals formed at the highest temperatures are chemically incompatible. Silica glass is found in nature as the rare fulgurites, and some tektites are high in silica. Fulgurites are formed by lightning striking sand, and marking its path by melting a long branching tube of silica glass. One such found at South Amboy, New Jersey, had a total length of nine feet and was three inches in diameter. Before Franklin discovered the true nature of lightning, fulgurites were supposed to be the remains of the lightning bolt.

Tektites have been found in many parts of the world, from Sweden to Tasmania. It has been suggested that they are distributed over the earth on a great circle and that they are volcanic bombs shot off from the moon. The origin of tektites, however, is still in dispute. A most plausible explanation of some occurrences is that they are the result of meteoric impact. Such an impact would produce a pool of molten material which would be splashed in all directions, thus producing the characteristic rounded shapes. This appears to be the only explanation of the fragments of silica glass, ranging in size from tiny bubbles to pieces weighing ten pounds, found scattered over an area of 75 square miles in the Libyan desert. The silica glass found in the Meteor Crater, Arizona, was undoubtedly formed by meteoric impact. It may be, however, that these highly siliceous materials are not properly called tektites, the large proportion of which have a lower silica content and resemble ordinary rock types.

XII. Conclusion

I have skimmed rapidly over several large fields of endeavor, in order to point out the features they have in common. All of them are concerned with the properties of silica and the silicates, of which properties the viscosity and tendency toward glass formation are the most outstanding. In carrying out this survey, my route has been that of the crystallizing magma, which, as cooling proceeds, continuously increases in silica content. The several branches of technology may conveniently be grouped in a similar manner, according to the proportion of silica commonly present in the product, and such a grouping serves to emphasize the many features common to all branches of silicate science.

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THE EFFECT OF IRON SURFACE PREPARATION UPON ENAMEL ADHERENCE*

By Karl Kautz

Abstract

Photomicrographs of iron surfaces prepared for enameling by various methods and these iron surfaces with attached ground-coat enamels at different stages of firing are shown. The results of adherence tests upon these various enameled surfaces are given.

I. Introduction

It has long been known that the different methods of preparing sheet-iron surfaces for vitreous enameling have a marked effect upon the bonding of the glass to the metal. Alkaline solutions which are used for cleaners and neutralizers have little effect upon the surface texture of iron and are not included in this study. Neutralizers, however, affect enameling operations by depositing films of adsorbed salts and of insoluble ferrous compounds upon the surface.

Different types of surface texture can be produced on sheet iron by a number of treatments in general use today. These treatments may roughly be listed as (1) cold rolling, (2) etching in dilute nonoxidizing acid solutions, (3) etching in dilute oxidizing acid solutions, (4) sandblasting, and (5) chemically plating with metallic nickel. Combinations of these various treatments are possible and also various modifications of each.

The purpose of this investigation was to study microscopically these various types of iron surface textures and to follow the changes they undergo during the firing of ground-coat enamels.

II. Procedure

To study microscopically these various surfaces both before and after enameling for various lengths of time in ground coat, carefully prepared specimens were necessary.

(1) Cold Rolling

A sheet of 18-gage enameling iron, after annealing, was pickled in dilute sulfuric acid to remove scale and then given a cold-roll treatment to 1% elongation. This sheet was made the basis for further treatments and was sheared into 5- by 7-inch samples, keeping adjacent samples grouped together.

(2) Etching in Dilute Nonoxidizing Acid Solutions

Three samples were etched in 6% sulfuric acid at 160°F for 15 minutes. The nonoxidizing acids in common use for etching iron surfaces are sulfuric and hydrochloric acids. Sulfuric acid in strong solutions and above 180°F often is oxidizing, but as ordinarily used in enameling practice it is nonoxidizing. Dilute solutions of both of these acids give almost the same type of surface texture, and sulfuric acid was chosen as representative of modern practice.

(3) Etching in Dilute Oxidizing Acid Solutions

Three samples were etched in 10% nitric acid at 140°F for five minutes. Other oxidizing acids which can be used to produce this type of surface are chromic, chloric, bromic, and perchloric. This type of surface may also be obtained by the addition of an oxidizing agent to dilute solutions of sulfuric or hydrochloric acids. Some oxidizing agents which give good results are sodium nitrate, sodium chlorate, sodium dichromate, sodium permanganate, ammonium persulfate, and manganese dioxide. The use of oxidizing acids, however, often necessitates mechanical scrubbing to remove sludges from the surfaces.

(4) Sandblasting

Three samples were carefully and deeply sandblasted in a commercial sandblasting machine. The production of sandblasted surfaces is well known in most enameling plants.

(5) Chemically Plating with Metallic Nickel

Three samples, after pickling in 6% sulfuric acid at 160°F for 4 minutes, were immersed in a boiling solution of nickel salts for $^1/_2$ minute. Another series of three samples was immersed for $7^1/_2$ minutes. This nickel solution contained 4 ounces of double nickel salts (nickel ammonium sulfate, $NiSO_4 \cdot (NH_4)_2SO_4 \cdot 6H_2O$) and $^1/_4$ ounce boric acid per gallon and had a p_H value of 6.4. Both double and single nickel salts ($NiSO_4 \cdot 6H_2O$) are used for chemically plating nickel in the industry with about equal results.

(6) Final Preparation

All samples were carefully rinsed in running

* Presented at the Thirty-Eighth Annual Meeting, American Ceramic Society, Columbus, Ohio, March 31, 1936 (Enamel Division). Received March 5, 1937.

FIG. 1.—(1A) cold-rolled; (2A) etched H_2SO_4; (3A) etched HNO_3.

water and then given a 5-minute immersion at 130°F in a solution containing 1 ounce per gallon each of sodium cyanide and sodium carbonate. Commercial cobalt ground-coat enamel was applied at $1^1/_4$ ounces per square foot dry to two samples of each treatment. One sample of each treatment was fired at 1600°F for $1^1/_4$ minutes, which permitted the ground coat just to fuse or gloss over. The remaining six samples were fired at 1600°F for 6 minutes, *i.e.*, to full maturity.

III. Microscopic Examination

Typical sections were cut and mounted from each prepared sample and were ground and polished perpendicular to the plane of the iron sheet surface. Photomicrographs were taken of typical views at magnifications of 1000 diameters using normally reflected light and bright field illumination. Cross-sections of the surface textures before enameling were etched in 10% nital to bring out the ferrite grains. Cross-sections of underfired specimens were not etched. Cross-sections of the normally fired specimens were etched in alcoholic stannous chloride to bring out the film of ferrous oxide between glass and iron and also to study the degree of diffusion of ferrous oxide in solution in the enamel.

Typical photomicrographs of this examination

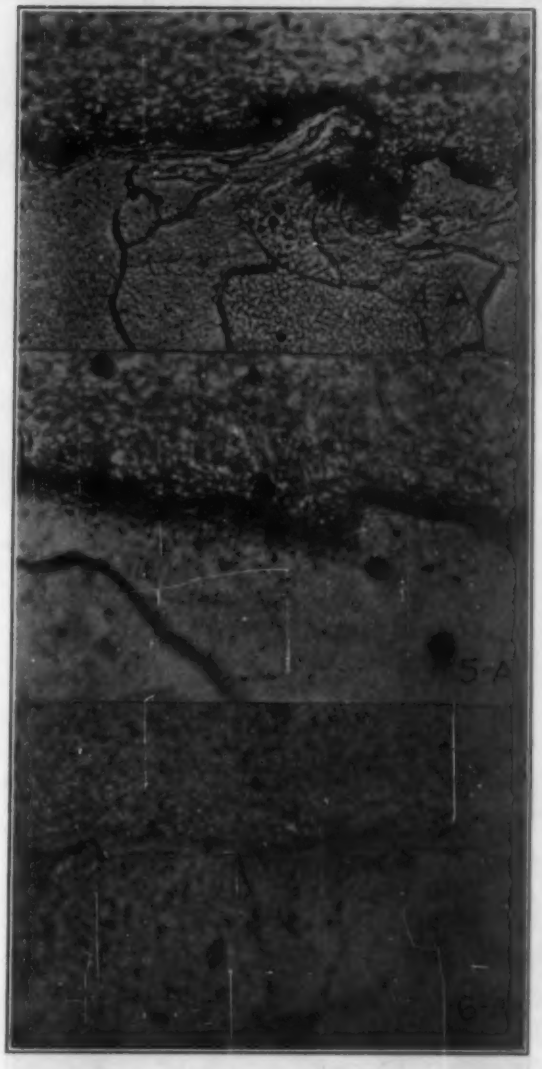

FIG. 2.—(4A) sandblasted; (5A) thin nickel plate; (6A) thick nickel plate: *top layer*, tin; *middle dark line*, nickel; *lower layer*, iron.

are shown in Figs. 1 to 6 (series (A), (B), and (C)). Series (A) shows cross-sections of the various iron-surface textures before enameling (the fine-grained material in contact with the iron surface being metallic tin used in mounting the specimens). Series (B) shows cross-sections of these surfaces immediately after fusion of the ground-coat enamel. Series (C) shows cross-sections of these surfaces after normally firing the ground-coat enamel.

IV. Results of Microscopic Studies

(1) Cold Rolling

Severe cold rolling produces a perfectly smooth surface and also a distortion of ferrite grains (see Figs. 1 (1A), 3 (1B), and 5 (1C). The degree of cold rolling shown in Fig. 1 (1A), however, is regarded as a light treatment and does not entirely eliminate all irregularities of the etched surface.

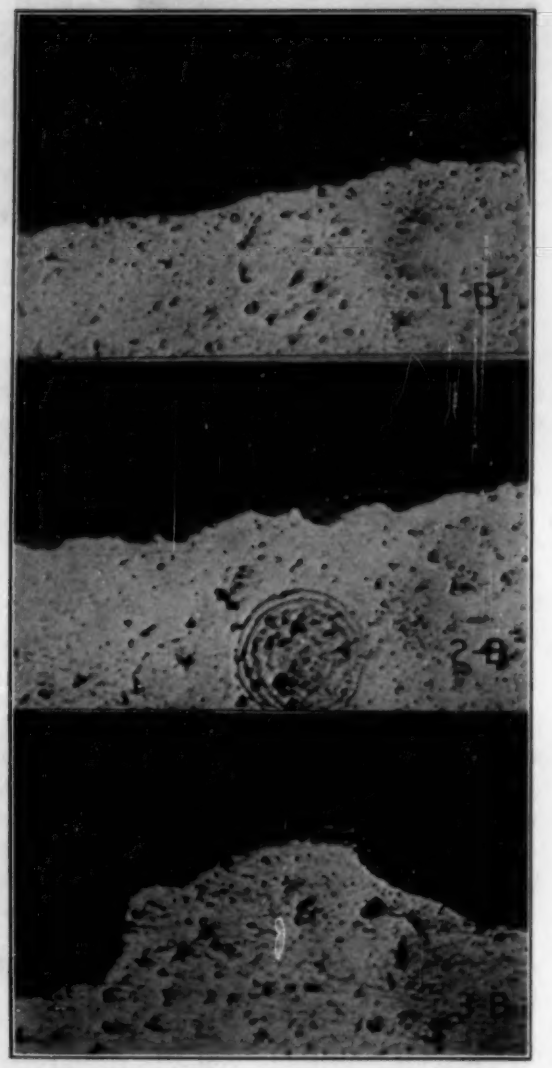

FIG. 3.—(1B), (2B), and (3B) fired 1¾ minutes.

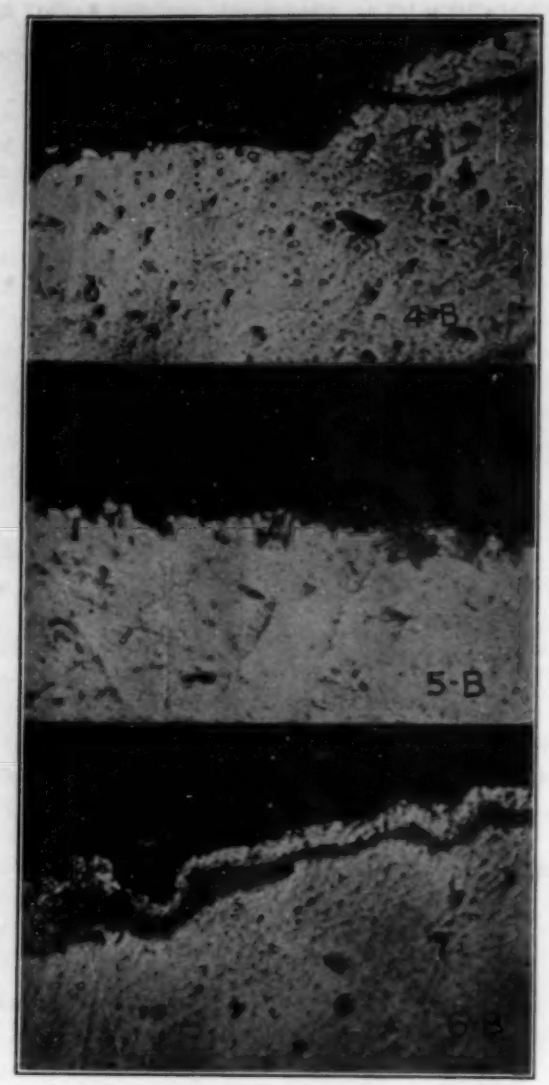

FIG. 4.—(4B), (5B), and (6B) fired 1¾ minutes.

Figure 3 (1B) shows the layer of initial scale formed prior to fusion of the glass particles. In some places this scale has a thickness greater than 0.00015 inch. It often extends continuously along the iron surface as shown. The iron surface underlying the scale is relatively smooth with no particles of residual iron visible.

Figure 5 (1C) shows the irregular nature of the iron surface after firing to the normal stage. Numerous irregular particles of residual iron have been undercut from the base and the surface

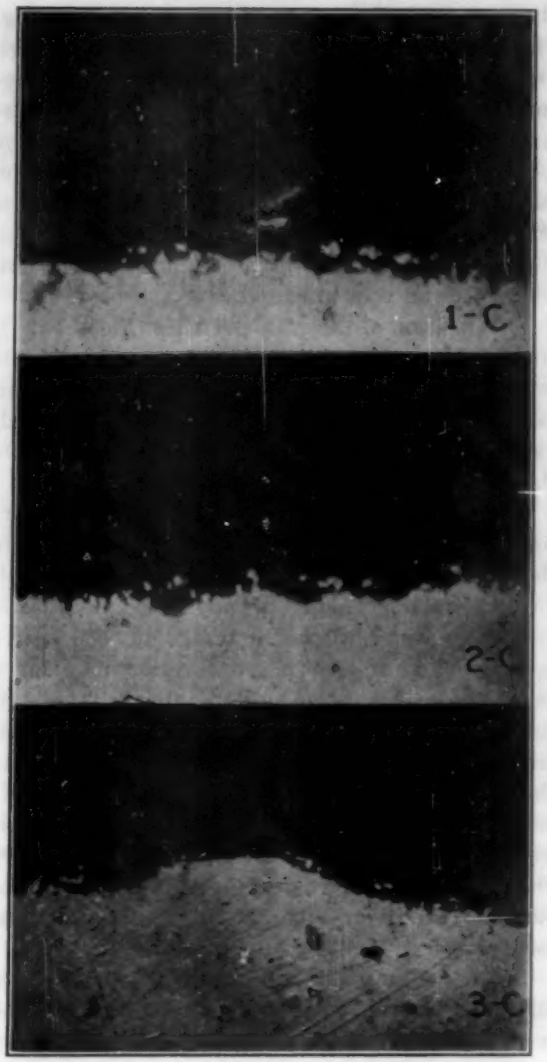

FIG. 5.—(1C), (2C), and (3C) fired 6 minutes.

shows numerous projections and indentations. The etchant makes visible what formerly was a film of ferrous oxide between the iron surface and the glass. This film is estimated to be about 0.00001 inch thick in this specimen. Adherence as estimated from impact tests was of average or normal degree.

(2) Etching in Dilute Nonoxidizing Acid Solutions

A surface texture typical of dilute sulfuric acid etching is shown in Fig. 1 (2A). This texture in cross-section appears to consist of tiny, relatively uniform, saw-tooth irregularities, which extend across the exposed surfaces of the grains. Each grain appears to be dissolving uniformly in the solution with no accelerated action at grain boundaries.

Figure 3 (2B) shows the layer of initial scale formed prior to fusion of the glass particles. This scale is 0.00015 inch thick in some places and is more or less continuous along the iron surface. The underlying iron surface, although originally saw-toothed from etching, is now relatively smooth and no undercut iron particles are visible.

Figure 5 (2C) shows the irregular surface developed in complete maturing of the enamel. Numerous loose particles of residual iron are

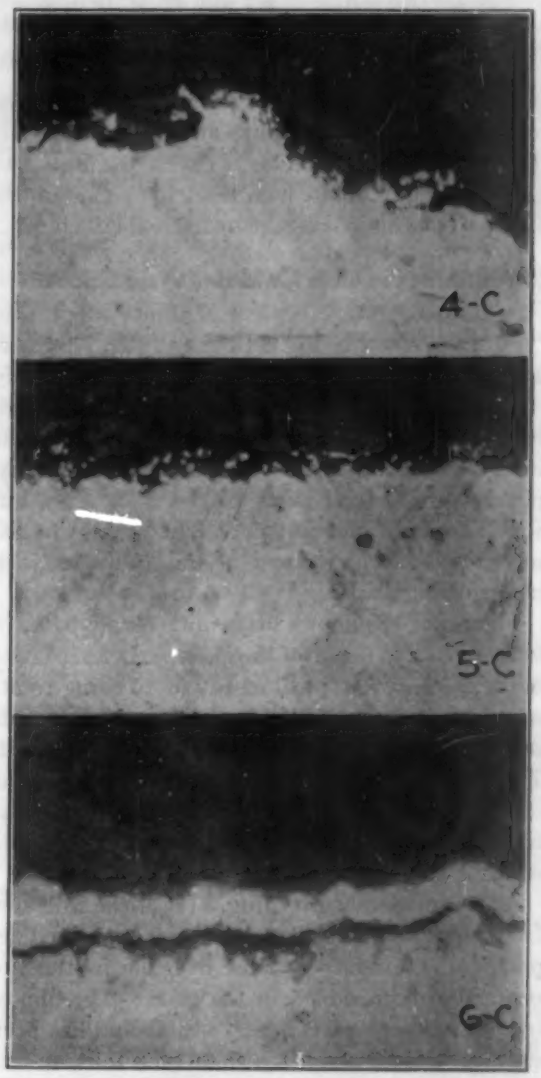

FIG. 6.—(4C), (5C), and (6C) fired 6 minutes. AUTHOR'S NOTE: The extremely thin film of ferrous oxide between glass and metal in Figs. 3C, 4C, and 5C is scarcely visible on these reproductions. It can, however, still be seen in the reproductions of Figs. 1C and 2C.

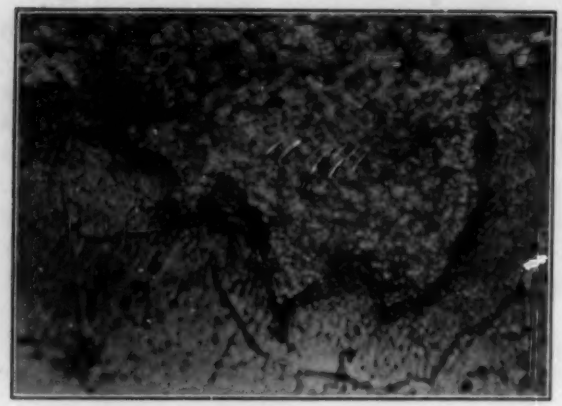

FIG. 7.—Iron surface etched with dilute HNO_3 showing almost complete solution of a ferrite grain; etched with 10% nital; ×1000.

present in the glass and many irregular projections and depressions are visible at the iron surface. The film of ferrous oxide between the iron and glass is about 0.00001 inch thick in this specimen. Impact tests show average or normal adherence.

(3) Etching in Dilute Oxidizing Acid Solutions

A surface texture typical of dilute nitric acid etching is shown in Fig. 1 (3A) and Fig. 7. Characteristic of this type of texture is the relatively smooth surface of the exposed ferrite grains, with resistant grains protruding outward at irregular intervals and the least resistant grains almost completely dissolved at other places. The chemical action is very rapid and the ferrite grains are dissolved selectively instead of uniformly as with nonoxidizing acids.

Figure 3 (3B) shows little initial scale to have formed prior to fusion of the glass particles. Loose particles of iron, typical of advanced firing treatment, are seen imbedded in the glass at intervals where no (or very little) initial scale has formed. The initial scale appears to form only at irregular intervals, which might be due to the easily oxidizable nature of certain ferrite grains. This scale is about 0.00007 inch thick.

At complete maturity, Fig. 5 (3C), the iron surface shows numerous irregular projections and depressions and numerous loose irregular particles of residual iron imbedded in the glass. The film of ferrous oxide phase is faintly visible and has been estimated to be about 0.000005 inch thick in this specimen. Impact tests show excellent adherence.

(4) Sandblasting

Figure 2 (4A) shows a typical section of the type of surface texture produced by sandblasting. The surface has an extremely jagged and rough appearance and shows occasionally tiny fragments of sand grains deeply imbedded. The surface appears to be torn and shredded and to be severely strained due to the peening effect of the sand grains at high velocity. Some ferrite grains appear to be more resistant to mechanical abrasion than others and remain protruding; others are deeply abraded or indented.

After fusion of the glass particles (Fig. 4 (4B)), the initial scale appears only at irregular intervals on the surface. Loose particles of residual iron are found where very little initial scale has formed. The initial scale, where it does form, sometimes has a thickness of 0.00012 inch.

An interesting feature of the sandblasted surface after fusing of the ground-coat particles is brought out by etching a specimen with nital. Although nital usually destroys the initial scale and loose iron particles, it brings out the ferrite grains. Figure 8 is a cross-section of such a specimen and is shown to illustrate the recrystallization of ferrite grains which takes place when this severely strained and shredded surface is heated to 1600°F for $1^3/_4$ minutes. For comparison, the normal size of ferrite grains in this specimen can be seen immediately below this layer of tiny recrystallized ferrite grains. No initial scale is visible. It either did not form in this area or it was destroyed by the nital etch.

Figure 6 (4C) shows the sandblasted surface after the ground coat was fired 6 minutes. A very irregular surface is obtained with many projections or promontories jutting into the enamel glass. Numerous loose particles of iron

FIG. 8.—Sandblasted surface after firing ground-coat enamel $1^3/_4$ minutes; etched in 10% nital; ×1000.

are also visible. The film of ferrous oxide is faintly visible and its thickness is estimated to be about 0.000007 inch in this section. Impact tests show excellent adherence.

(5) Chemically Plating with Nickel

Two series are shown to illustrate the effect of proper and improper application. Figures 2 (5A), 4 (5B), and 6 (5C) show good practice and are samples immersed in a boiling nickel salt solution for $^1/_2$ minute. Figure 2 (5A) shows a lightly pickled surface with a film of metallic nickel attached. This film is difficult to observe but can be seen as a thin broken white line at the surface.

After fusion of the glass particles (Fig. 4 (5B)), the nickel is seen as tiny particles at the surface. Where the iron surface was unprotected, rapid oxidation took place and pockets of initial scale formed at irregular intervals. These pockets are small compared with the initial scale areas obtained on sulfuric acid etched surfaces although their thickness may be 0.00012 inch in some places.

The normal stage is shown in Fig. 6 (5C). A very irregular surface is obtained with many irregular projections and depressions. A great number of loose metallic particles are seen imbedded in the glass. In this case, both nickel particles and residual iron particles probably are present. The film of ferrous oxide at the interface is but faintly visible and is estimated to be about 0.000005 inch thick. Impact tests show excellent adherence.

Figures 2 (6A), 4 (6B), and 6 (6C) show the effects of plating nickel too heavily upon the iron surface. This heavy coating or plate of nickel can easily be seen adhering to and completely covering the iron surface in Fig. 2 (6A). The thickness of this spongy plate of nickel varies between 0.0001 and 0.0002 inch thick.

Figure 4 (6B) shows this nickel-plated iron after fusion of the glass particles. The most remarkable fact is that this plate of spongy nickel does not prevent oxidation of the iron surface prior to fusion of the ground coat. Oxygen diffused through this nickel layer without visibly oxidizing it and preferentially combined with iron. A layer of initial scale can easily be seen between the iron surface and the nickel coating. The scale thickness in this specimen varies between 0.00005 and 0.00025 inch. The surface of the iron base underlying this initial scale is relatively smooth, similar to Fig. 3 (1B) and (2B) and indicates rapid oxidation.

Figure 6 (6C) shows this heavy nickel-covered iron after firing the ground coat 6 minutes. The absence of the characteristic cracks in the ground coat will be noted. A previous investigation[1] led to the conclusion that these cracks, which are evident in most of the specimens labeled "C" in the photomicrographs, are present when ferrous oxide is dissolved in the glass, but otherwise are absent. It may therefore be concluded that this figure depicts a condition in which ferrous oxide is not dissolved in the glass. There are no loose metallic particles imbedded in the glass and the nickel layer in contact with the glass appears as originally deposited. Solution of the initial scale has been prevented by the nickel covering, but aerial oxygen diffusing through the molten glass, nickel plate, and initial scale has made an additional attack on the iron surface. This surface is no longer smooth as in Fig. 4 (6B), but quite irregular with many projections and depressions. Many particles of iron undercut from the iron base are seen imbedded in the scale. This irregular iron surface was not produced by any chemical reaction between ground-coat glass and iron (because they were never in contact) but solely by the retarded reaction of aerial oxygen diffusing through the layers of molten glass, nickel, and scale. Impact tests show very poor adherence.

V. Conclusions

From the results of this microscopic study, a number of deductions and conclusions have been made.

The original roughness or smoothness of the iron surface before enameling seems to have little effect upon the ultimate adherence. The smooth cold-rolled surface and the rough sulfuric acid-etched surface show equal impact tests. The sandblasted surface (the roughest of all surfaces) shows no better adherence than the comparatively smooth, thinly nickel-plated surface.

The characteristic iron surface under normally fired ground coats with its irregular projections and depressions is produced by slow oxidation and not by chemical reactions between glass and iron. This type of iron surface appears under the scale

[1] Karl Kautz, "Further Data on Enamel Adherence," *Jour. Amer. Ceram. Soc.*, **19** [4] 93–108 (1936).

layer of Fig. 6 (6C) and is identical with other normally fired ground coats. The projections are slightly larger and coarser in this case due perhaps to a different rate of oxidation.

Oxidation of the iron surface prior to fusion of the glass particles is retarded by treatment with oxidizing acids, by sandblasting, and by plating with nickel. This is readily seen from a study of the photomicrographs of series (B) (Figs. 3 and 4).

When thick continuous layers of initial scale form prior to fusion of the glass particles, the adherence obtained is not maximum. Since the initial scale is dissolved by the glass, it follows that the more ferrous oxide in solution in the glass the poorer the adherence becomes. The degree of adherence seems to depend upon the thickness of the ferrous oxide film between glass and iron. The thicker this film, the poorer the adherence becomes.

There seems to be no relation between the degree of irregularity of surface (small irregular projections and depressions) under normally fired enamels and the degree of adherence. Figure 5 (1C) and (2C) shows about the same degree of irregular surface as Figs. 5 (3C) and 6 (4C) and (5C), but the impact tests on samples (1C) and (2C) show inferior adherence.

There seems to be no relation between the number and size of irregular particles of residual iron in the glass and the degree of adherence. Most normally fired ground coats show undercut iron particles near the iron surface although the adherence may vary from poor to good.

VI. Discussion

(1) Treatments Producing Average Adherence

Lightly cold-rolled iron and iron etched in dilute nonoxidizing acid solutions showed average to good adherence depending upon how the ground coat was fired. Under typical conditions, considerable scale was formed prior to fusion of the glass particles. The solution of this scale produced high ferrous oxide concentrations near the interface so that relatively thick films of ferrous oxide between glass and iron resulted in the normal stage.

(2) Treatments Producing Excellent Adherence

Iron etched in dilute oxidizing acid solutions, sandblasted, or given a light chemical plate of nickel showed excellent adherence under most firing conditions. Thin discontinuous layers of initial scale were formed in the scale formation stage, which resulted in a low ferrous oxide concentration at the interface in the normal stage of firing. Relatively thin films of ferrous oxide (faintly visible at 1000 diameters) between glass and iron resulted.

(3) Solution of Initial Scale

In general, large amounts of ferrous oxide dissolved in the ground-coat glass caused poor adherence and small amounts promoted good adherence. This may be due to saturation of the glass with ferrous oxide at the contact surface in the first case so that the rate of solution is greatly retarded and thicker films of ferrous oxide remain between glass and iron. With unsaturated glass at the contact surface, as in the second case, solution proceeds rapidly, and thinner films of ferrous oxide remain between glass and iron, resulting in better adherence.

(4) Formation of Initial Scale

The importance of initial scale formation is emphasized by these experiments. It seems desirable that the formation of initial scale be controlled and only a small amount be allowed to form in the firing of ground-coat enamels. The formation of initial scale during the early stages of ground-coat firing is influenced by (1) the thickness of the dried coat, (2) the porosity of the dried coat, (3) the softening point of the glass, (4) the rate of heating, (5) the composition of the firing chamber atmosphere, (6) the rate of flow or circulation of the firing chamber gases, and (7) the character of the iron surface. The character of the iron surface as influenced by the different types of surface texture is considered here. Neutralizer films also affect the character of the surface but probably exert only a minor influence in the formation of initial scale.

(5) Oxidizing Acids

It has been shown that a selective solution of ferrite grains takes place in oxidizing acid solutions. Ferrite grains that are oriented in such a manner that they have high resistance to solution in oxidizing acids are believed also to have high resistance to oxidation. It seems that oxidizing acids tend to purify or refine the iron surface by dissolving selectively those ferrite grains which

have low resistance because of their orientation and by leaving predominant those of high resistance. Although this refinement is never perfectly attained, the surface as a whole tends to become more resistant to oxidation.

(6) Sandblasting

Sandblasting appears to produce mechanically the same kind of refinement that oxidizing acids produce chemically. Ferrite grains that are oriented in such a manner that they have high resistance to abrasion or impact (high hardness) are possibly the same ones that have high resistance to oxidation. This refining of the iron surface is less completely attained with sandblasting than with oxidizing acids, but the general trend would be to make the surface as a whole more resistant to oxidation. The straining of the ferrite grains at the sandblasted surface may also be a factor in retarding the rate of oxidation.

(7) Nickel Plating

Chemically plating with nickel undoubtedly acts only in a protective manner. Nickel is one of the few common metals that possess high resistance to oxidation, and when a thin plate is applied compactly and uniformly to the iron surface, it tends to retard the rate of oxidation of the iron during the scale formation period.

(8) Commercial Applications

Oxidizing acids can be used in enameling plants although they possess the disadvantage that sludges often form on the surface of the ware necessitating mechanical or hand scrubbing of each piece.

Sandblasting is practiced to a considerable extent at the present time on certain large or heavy gage parts, but it is an expensive operation and is unsuitable for parts of light gage.

Chemically plating with nickel seems to be the most practical method of the three mentioned for enameling plant use. It is inexpensive and fits into the regular procedure with but little additional handling. Being a plating treatment, this operation must be carefully controlled or injurious results will be obtained. The nickel layer must never be allowed to deposit too thick or in a loose, spongy manner. Temperature control, time of immersion, and p_H value are important.

VII. Summary

Lightly cold-rolled sheet iron with no further treatment, and the same after etching in dilute nonoxidizing acids, shows considerable scale after fusion of the ground coat. At the normal stage, this scale is in solution in the glass. Sheet iron etched in dilute oxidizing acid solutions, sandblasted, or given a very thin plate of nickel, shows smaller amounts of initial scale after fusion and therefore less ferrous oxide in solution in the glass at the normal stage.

Excellent adherence seems to result when the amount of ferrous oxide dissolved in the glass at the normal stage is not excessive.

Iron surfaces can be made more resistant to oxidation (*a*) chemically by the use of oxidizing acids, (*b*) mechanically by sandblasting, and (*c*) protectively by the use of thin nickel plates. Of these three methods, chemically plating with nickel is the most suitable and least expensive generally for use in enameling plants.

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ELASTIC AND VISCOUS PROPERTIES OF SEVERAL SODA-SILICA GLASSES IN THE ANNEALING RANGE OF TEMPERATURE*

By Nelson W. Taylor and Paul S. Dear†

Abstract

Measurements have been made on "stabilized" glass fibers of five compositions in the system soda–silica, at several temperatures in the annealing range, to obtain the viscosity, Young's modulus for instantaneous and total elasticity, and the rate of delayed elastic distortion for each glass. Values for the activation energy for viscous flow and delayed elastic distortion have been derived from the temperature coefficients. An ionic theory of the elastic and viscous processes and a discussion of binding energies in the system soda–silica are presented.

I. Introduction

The viscous properties of glass, to a large extent, dominate many of the problems of manufacture. Among the fundamental physical properties of glass, one of the most important, therefore, is its flow characteristics.

In this country, the work of Lillie,[1] using the fiber elongation method, has been outstanding in viscosity studies on glass in its nearly "rigid" condition. Several investigators have recently used the fiber elongation method to study the flow relations of various glasses at temperatures near their softening interval. In this connection, the work of Volarovich and Leontieva[2] on quartz glass, of Bair[3] on lead oxide-silica glasses, and of Taylor, McNamara, and Sherman[4] on a soda-lime-silica glass may be cited. From the work of these investigators, it appears that the flow relations of other glass-forming systems at temperatures near their softening interval are worthy of further study.

It should be emphasized that the past thermal history (of the glass) and the time element are important factors to be considered in testing the physical properties of glass. This has been pointed out by Lillie,[1(b)] Littleton,[5] and Morey.[6] These factors will be taken into consideration during the present investigation.

Before proceeding to a detailed description of the investigation, it seems advisable to define certain terms pertinent to the experiments and discussions which follow.

An *elastic body* may be defined as one which returns to its original shape after the removal of an externally applied distorting force; since this definition does not contain time as a variable, the elastic effect may be either sudden, or delayed, or any combination of the two.

A *viscous body* may be defined as one which is deformed continuously at a constant rate under the influence of an external force. Upon removal of the force, a permanent deformation exists, the magnitude of which is proportional to the magnitude of the applied external force and to the duration of its application.

Elastico-viscous properties, then, are those properties which arise from a combination of elastic and viscous effects consistent with the above definitions. The terms elastic distortion, viscous flow, and elastico-viscosity, when used in this paper, will conform to these definitions.

The term, *stabilized glass*, may be defined as a glass whose uncertain thermal history has been removed by thorough heat treatment at the temperature of the test until (insofar as present laboratory methods permit of disclosure) it has assumed the equilibrium property values characteristic of the glass at that temperature.

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* Presented at the Thirty-Ninth Annual Meeting, American Ceramic Society, New York, N. Y., March 23, 1937 (Glass Division).

† Submitted in partial fulfillment of the requirements for the degree of Master of Science, The Pennsylvania State College, 1937.

[1] (*a*) H. R. Lillie, "Viscosity of Glass between Strain Point and Melting Temperature," *Jour. Amer. Ceram. Soc.*, **14** [7] 502–11 (1931).

(*b*) H. R. Lillie, "Viscosity-Time-Temperature Relations in Glass at Annealing Temperatures," *ibid.*, **16** [12] 619–31(1933).

[2] M. P. Volarovich and A. A. Leontieva, "Viscosity of Quartz Glass within the Softening Range," *Jour. Soc. Glass Tech.*, **20**, 139–43 (1936); *Ceram. Abs.*, **16** [1] 11 (1937).

[3] G. J. Bair, "Constitution of Lead Oxide-Silica Glasses: II, Correlation of Physical with Atomic Arrangement," *Jour. Amer. Ceram. Soc.*, **19** [12] 347–58 (1936).

[4] N. W. Taylor, E. P. McNamara, and Jack Sherman, "Study of the Elastico-Viscous Properties of a Soda-Lime-Silica Glass at Temperatures near the 'Transformation Point,'" *Jour. Soc. Glass Tech.*, **21** [83] 61–81 (February, 1937).

[5] J. T. Littleton, "Critical Temperatures in Silicate Glasses," *Ind. Eng. Chem.*, **25** [7] 748–55 (1933); *Ceram. Abs.*, **12** [10–11] 360 (1933).

[6] G. W. Morey, "Constitution of Glass," *Jour. Amer. Ceram. Soc.*, **13** [11] 315–28 (1934).

Elastico-viscous flow of glass is by no means a newly observed phenomenon. Michelson[7] discussed these effects and from torsional tests arrived at an empirical expression which Stott[8] applied to glass rods subjected to longitudinal tension. In his flow studies, Bair[3] derived an empirical equation relating elongation and time during the delayed part of the elastico-viscous flow. Continuing the flow studies of Bair, the elongation rate data were analyzed into three parts by Taylor, McNamara, and Sherman,[4] who pointed out the significance of the rate constant for the delayed elastic distortion.

With the above background in mind, fibers drawn from several different glasses in the system sodium oxide–silica have been "stabilized" and subsequently subjected to longitudinal tension. The resultant elastico-viscous effects have been analyzed and discussed.

II. Composition of Glasses Studied

Five commercially melted glasses[9] in the system $Na_2O{\cdot}SiO_2$–SiO_2 were available for the experiments to be described later in this paper. The compositions of these glasses are shown in Table I. The composition of glass X is not included, but its composition falls between that of glasses SSC and No. 2.

TABLE I

CHEMICAL COMPOSITION OF GLASS FIBERS

Glass	Na_2O (wt. %)	SiO_2 (wt. %)	Ratio Na_2O/SiO_2
SSC	33.02	65.66	1:1.988
No. 2	27.84	70.89	1:2.546
SS	23.46	75.83	1:3.232
No. 1	19.84	79.00	1:3.981

The glass compositions fall within a limited region of the field between the end members of the binary system, $Na_2O{\cdot}SiO_2$–SiO_2. The lower limit of SiO_2 is fixed at about $1Na_2O:1.5SiO_2$ by the tendency of the resulting glass to devitrify. The upper limit of SiO_2 is governed by the high temperature necessary for proper melting of the glass and the relatively high temperatures necessary to study the properties pertinent to this investigation.

[7] A. A. Michelson, "Laws of Elastico-Viscous Flow," *Jour. Geol.*, **25**, 405 (1917).

[8] (*a*) V. H. Stott, "Viscosity of Glass," *Jour. Soc. Glass Tech.*, **9**, 207–25 (1925); *Ceram. Abs.*, **5** [2] 47 (1926).
(*b*) V. H. Stott, "Viscous Properties of Glass," *Jour. Soc. Glass Tech.*, **10**, 424–34 (1926); *Ceram. Abs.*, **6** [6] 214 (1927).

[9] Donated through the courtesy of the Philadelphia Quartz Co., Philadelphia, Pa.; analyses furnished by Daniel B. Curll.

III. Preparation of Glass Fibers

The commercially melted glasses were crushed to pass a 10-mesh sieve. Tramp iron was removed by a strong magnet. Approximately 25 grams of prepared cullet from each glass was remelted in a platinum crucible within a platinum-wound resistance furnace. The temperature was held above 1400°C for three hours, followed by a one-hour treatment above 1475°C to complete the fining. It was necessary to fine the high silica glass, No. 1, at a higher temperature of 1575°C in order to acquire homogeneity.

The glass melt was cooled to within the working range, and fibers were drawn mechanically from the center of the melt. The drawing bait was raised vertically by a cable passed over a pulley and attached to the shaft of a speed reducer. With a cable speed of 1.5 feet per minute excellent fibers, approximately 8 feet in length, were obtained from each melt.

From these fibers approximate 25-centimeter lengths, whose average diameters were approximately 0.070 ± 0.002 centimeter as determined by micrometer calipers, were selected. These selected fibers were sorted further by immersion in a solution of C_6H_6 and CS_2 whose refractive index matched that of the glass. Only those fibers which were free of cords, seeds, and other inhomogeneities were selected for the experiments.

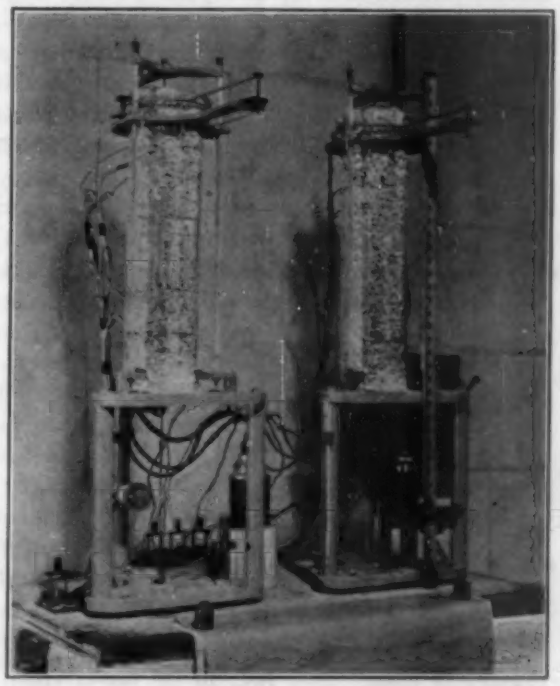

FIG. 1.

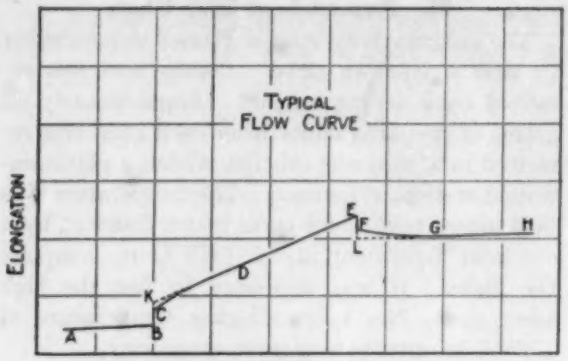

FIG. 2.

IV. Description of Apparatus

The apparatus used in the experimental work was like that described by Norton[10] and used by several investigators for the determination of the viscosity of glasses at relatively low temperatures (see Fig. 1).

The furnace consisted essentially of a heavy-walled stainless steel furnace tube wrapped with mica tape and wound with nichrome wire. The furnace was covered with high temperature pipe-cover insulation. The furnace winding was divided into three separate parts so that the temperature gradient along the length of the furnace could be accurately controlled by adjusting the current through each separate part. The average temperature of the furnace was maintained automatically at a constant value by the change in length of the furnace tube. The expansion and contraction of the furnace tube was magnified about fifty times by a lever arrangement which alternately opened and closed contacts, alternately disconnecting and connecting a resistance in parallel with the main current regulating rheostat, and allowing accurate mean temperature control. For instance, over long periods of time the average temperature could be maintained within limits of $\pm$ 0.4°C of the mean average temperature. The temperature, moreover, at any point along the length of the test specimen could be maintained within $\pm$ 0.25°C of the average temperature.

The temperatures were recorded at frequent intervals by means of three standardized chromel-alumel thermocouples located very near the top, center, and bottom of the test fiber, and connected to a Leeds and Northrup type K potentiometer.

The accurately calipered homogeneous fiber of known length and uniform diameter was beaded at each end to accommodate the socket-like hangers. The fiber was suspended in the furnace by resting the upper hanger on a rigid frame-work at the top of the furnace. The lower hanger, to which the required weights could be attached, projected from the bottom of the furnace. The changes in length of the test fiber were measured by means of a traveling microscope rigidly attached to the rigid base of the furnace. By sighting the microscope cross-hair on a fine scratch on the lower hanger, changes in length of the fiber could be measured to 0.0002 centimeter.

V. Experimental Procedure

Each fiber was tested in a manner similar to that employed by recent investigators of elastico-viscous flow relations in glass.[11] The fiber under test was suspended within the furnace with the load of the lower hanger acting upon it until the rate of elongation became constant and remained so for a considerable period of time. It is felt that such heat treatment effectively stabilized the glass fiber at the temperature of test, since the elongation *vs.* time curves were reproducible after such treatment.

After stabilization was considered complete, a suitable weight was attached to the lower hanger, and the resulting rate of elongation was measured with the traveling microscope until the rate again became constant. The weight was removed and the rate of contraction was measured until elastic recovery was complete. Weights were varied

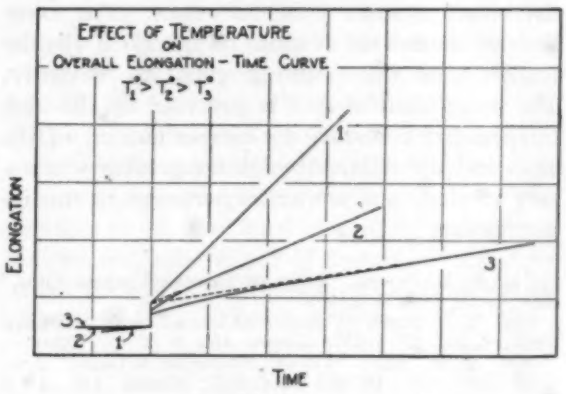

FIG. 3.

[10] F. H. Norton, "New Apparatus for Measuring the Viscosity of Glass," *Glass Ind.*, **16** [5] 143–44 (1935); *Ceram. Abs.*, **14** [7] 160 (1935).

[11] See footnotes 3 and 4, p. 296.

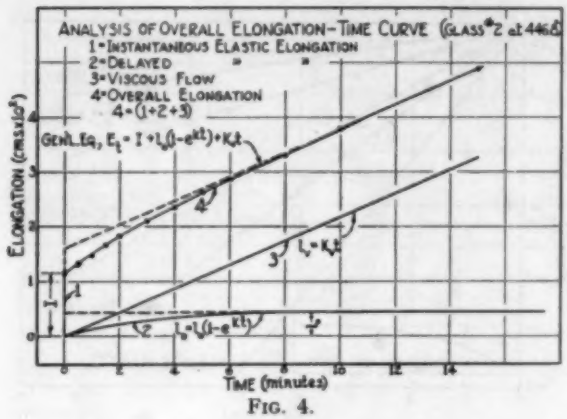

FIG. 4.

from 100 to 1000 grams, depending upon the temperature of test. The time intervals between readings were varied in accordance with flow rates, *viz.*, short intervals for fast rates and long intervals for slow rates of flow.

A typical curve, depicting the progress of the flow during this experiment is shown in Fig. 2, where the ordinates are overall elongations and the abscissas are the corresponding times. The cycle of flow may be traced as follows: the fiber is heat-treated at the temperature of test until a constant rate of flow, *AB*, is attained. Upon application of load to the stabilized fiber, an instantaneous elastic elongation, *BC*, occurs. This is followed by a combination of delayed elastic elongation and true viscous flow which results in an elongation curve, *CD*, whose rate decreases until it attains finally a constant value, *KDE*. Upon removal of load, an immediate elastic contraction, *EF*, occurs. This is followed by a period, *FG*, during which the delayed elastic contraction opposes the true viscous flow owing to the load of the lower hanger. The resulting curve, *FGH*, shows a rate which decreases through zero and is followed by the attainment of the previous constant rate of elongation (*LGH* parallel to *AB*). It should be emphasized that the elastic effects are completely reversible and reproducible.

The effect of temperature on the overall elongation-time curve is shown in Fig. 3. It is to be noted that the instantaneous elastic elongation increases as the temperature of test is increased, and the time necessary for the delayed elastic distortion to be completed becomes shorter as the temperature is raised.

VI. Analysis of Data

The overall elongation-time data may be resolved (Fig. 4) into three component parts, (1) an immediate elastic elongation, completed very rapidly, (2) a delayed elastic elongation, proceeding more slowly and approaching its limiting value asymptotically, and (3) a viscous flow, proceeding at a constant rate. The magnitudes will depend, of course, upon the composition of the glass, the temperature, and the applied load.

In terms of these components, the overall elongation at any time is given by their sum as expressed in the following formula[4]:

$$E_t = I + l_o(1 - e^{kt}) + k_v t$$

Where E_t = overall elongation at time, t.
I = instantaneous elastic elongation.
l_o = total delayed elastic elongation.
e = base of natural logarithms.
k = rate constant for delayed elastic process, or fractional change in unstretched length per unit of time.
t = time.
k_v = constant rate of viscous flow.

The rate of viscous flow, k_v, was determined by application of the theory of least squares to the latter part of the overall elongation-time curve, *i.e.*, after the delayed effect was completed. Determination of k_v was necessary for the calculation of viscosity.

The curve representing the delayed elastic elongation could be readily obtained by subtracting the viscous flow and the instantaneous elastic elongation from the overall elongation. Application of the least squares theory to the resultant data permitted calculation of the rate constant, k, for the delayed elastic process. A check of the method will be discussed later.

VII. Results of Experiments

(1) Viscous Flow

The following formula, experimentally verified by Lillie[1(a)] and others, was used in calculating the viscosity:

$$\eta = \frac{80\ MgL}{\pi\ D^2 k_v}$$

Where η = viscosity (c.g.s. units or poises).
Mg = applied load (dynes).
L = length of fiber (cm.).
D = diameter of fiber (cm.).
k_v = rate of elongation (cm./min.).

It should be emphasized that k_v is the constant rate of viscous flow obtained after the delayed elastic effect is complete.

The viscosity values calculated from the experimental data are given in Table II, the individual values being within 5% of the average values reported.

TABLE II
VISCOSITY OF "STABILIZED" GLASSES AS A FUNCTION OF TEMPERATURE

Temp. (°C)	Viscosity (poises)	$10^4/T$
Glass SSC		
427.8	1.6×10^{14}	1.427
446.6	7.6×10^{13}	1.389
456.0	2.1×10^{13}	1.372
459.1	1.4×10^{13}	1.366
466.0	4.6×10^{12}	1.353
471.0	2.2×10^{12}	1.344
Glass X		
435.0	9.5×10^{13}	1.412
442.9	3.6×10^{13}	1.397
452.5	8.6×10^{12}	1.378
469.8	5.8×10^{11}	1.346
Glass No. 2		
427.7	6.8×10^{14}	1.427
442.2	6.4×10^{13}	1.398
446.8	3.7×10^{13}	1.389
452.5	1.5×10^{13}	1.378
455.9	1.0×10^{13}	1.372
459.2	6.7×10^{12}	1.366
466.0	2.4×10^{12}	1.353
471.0	1.3×10^{12}	1.344
Glass SS		
442.2	1.2×10^{14}	1.398
446.8	6.6×10^{13}	1.389
452.5	2.7×10^{13}	1.378
456.0	2.1×10^{13}	1.372
459.3	1.3×10^{13}	1.365
466.0	5.0×10^{12}	1.353
471.5	2.8×10^{12}	1.343
Glass No. 1		
442.4	8.2×10^{14}	1.398
447.0	3.7×10^{14}	1.389
452.5	1.8×10^{14}	1.378
456.0	1.1×10^{14}	1.372
459.3	7.1×10^{13}	1.365
466.0	2.6×10^{13}	1.353
471.2	1.6×10^{13}	1.344

Figure 5 shows graphically the relation between $\log_{10}\eta$ and $1/T$ over the temperature range employed. For any glass the plot may be

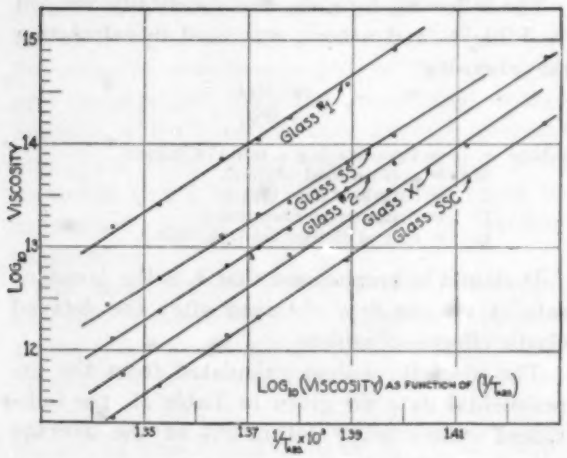

FIG. 5.

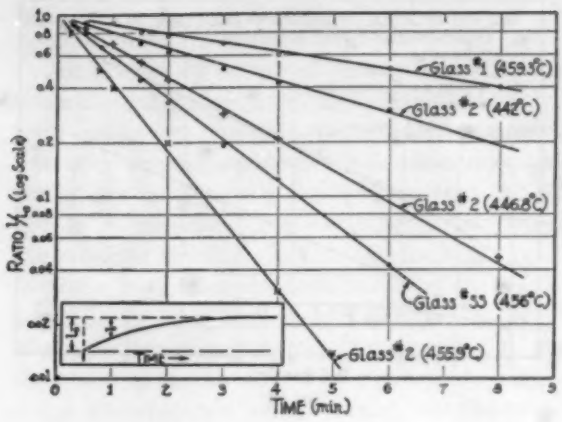

FIG. 6.

represented very closely by a straight line of the form,

$$\text{Log}_{10}\eta = A\left(\frac{1}{T}\right) + B.$$

It is to be noted that the slope, A, for the various glasses is nearly constant over the range of compositions studied. A re-plot of Bair's viscosity values[3] for a series of lead oxide-silica glasses, using the same ordinate and abscissa representation, shows quite similar parallelism.

A similar parallelism in electrical conductivity property curves has been observed by Seddon, Tippet, and Turner.[12] Quoting these investigators,

"It appears that the main portion of the graph obtained (plotting log specific resistance against $1/T$) is, for the sodium metasilicate-silica glasses, approximately a straight line, as it is for other glasses examined by several investigators previously. The graphs for the different glasses are approximately parallel."

The slopes, A, of the $\log_{10}\eta$ against $1/T$ plots are shown in Table III, with additional data gathered from other comparatively recent studies.

(2) Delayed Elastic Effect—Rate Constants

As previously explained, the delayed elastic component of the overall elongation-time curve may be readily obtained. In Fig. 6 (inset), l_0 is the total delayed elastic elongation; l is the distance from equilibrium at time, t. If dl/dt is the rate of elongation at time, t, it can be shown that for a stabilized fiber $dl/dt = kl$.

[12] E. Seddon, E. J. Tippet, and W. E. S. Turner, "Electrical Conductivity of Sodium Metasilicate-Silica Glasses," *Jour. Soc. Glass Tech.*, **16**, 450–77 (1932); *Ceram. Abs.*, **12** [7] 257 (1933).

TABLE III

TEMPERATURE COEFFICIENT OF VISCOSITY OF SEVERAL TYPES OF GLASSES

Type of glass	Range of viscosity		$\frac{\Delta \log_{10}\eta}{\Delta (1/T) \times 10^4}$ = slope A Individual value	Mean value
Quartz glass (Volarovich and Leontieva)*	10^{10}–10^{15} poises		41.7	41.7
Soda-lime-silica (Lillie)**	10^{12}–10^{15} poises		37.0	35.3
Soda-lime-silica (McNamara)†	10^{12}–10^{15} poises		33.6	
Soda-silica (present investigation)	10^{11}–10^{13} poises	No. 1 glass	33.4	33.0
		SS glass	31.5	
		No. 2 glass	32.6	
		X glass	33.8	
		SSC glass	33.9	
Lead-silica (Bair)‡	10^{11}–10^{13} poises	No. 30 glass	31.8	32.7
		No. 40 glass	34.4	
		No. 50 glass	29.0	
		No. 60 glass	35.6	

* See footnote 2, p. 296.
** See footnote 1 (*b*), p. 296.
† See footnote 4, p. 296.
‡ See footnote 3, p. 296.

Integration of this expression gives

$$\text{Log}_{10}\frac{l}{l_o} = \frac{k}{2.303}t \text{ or, removing logarithms,}$$

$$\frac{l}{l_o} = e^{kt}.$$

The rate constants, k, were determined from the delayed elastic elongation-time data for the various glasses at each temperature of test by application of the method of least squares. If these equations are satisfactory, a plot of $\log_{10} l/l_o$ versus t should give a straight-line relation. Figure 6 shows graphically the efficacy of these equations.

Table IV gives the values of the rate constants for the various glasses in the temperature range of the experiments.

(3) Rate Relations

The quantitative relation between the rate constants, k, and the corresponding absolute temperature, T, is given by the equation,

$$\frac{d \log_e k}{dT} = \frac{A}{RT^2}$$

Where A = a constant with dimensions of energy, and represents energy of activation of rate-controlling process.

Integrating this expression between limits and passing to Briggsian logarithms gives

$$\text{Log}_{10}\frac{k_2}{k_1} = \frac{A}{2.3R}\left(\frac{1}{T_1} - \frac{1}{T_2}\right).$$

Accordingly, plotting the logarithms of the rate constants against the reciprocals of the corresponding absolute temperatures should give a straight line whose slope permits the calculation of the energy of activation. Such a plot is shown in Fig. 7.

Calculation of the energy of activation, A, for the various glasses gives the following results (see page 302):

TABLE IV

RATE CONSTANTS FOR DELAYED ELASTIC DISTORTION AS A FUNCTION OF TEMPERATURE

Temp. (°C)	Rate constant (k)	$10^4/T$
Glass SSC		
427.8	−0.079	1.427
446.6	− .62	1.389
456.0	−1.4	1.372
Glass X		
435.0	−0.14	1.412
442.9	− .30	1.397
452.5	− .86	1.378
Glass No. 2		
427.7	−0.052	1.427
442.2	− .21	1.398
446.8	− .39	1.389
452.5	− .69	1.378
455.9	− .83	1.372
Glass SS		
442.2	−0.10	1.398
446.8	− .20	1.389
452.5	− .35	1.378
456.0	− .53	1.372
459.3	− .79	1.365
Glass No. 1		
442.4	−0.010	1.398
447.0	− .017	1.389
452.5	− .035	1.378
456.0	− .058	1.372
459.3	− .11	1.365
466.0	− .27	1.353
471.2	− .52	1.344

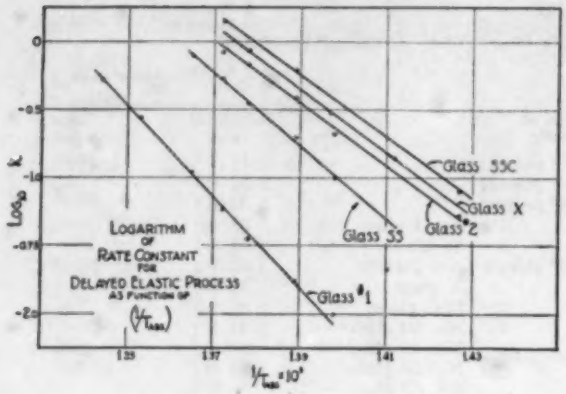

FIG. 7.

Glass	A (cal./N)
SSC	105,000
X	106,000
No. 2	106,000
SS	122,000
No. 1	153,000

The quantity $N = 6.06 \times 10^{23}$ represents the Avogadro number of elementary processes occurring.

A value of 160,000 cal./N was found for the soda-lime-silica glass studied by Taylor, McNamara, and Sherman.[4]

A similar calculation of an energy term from the approximately constant slope of the $\log_{10}\eta$ against $1/T$ curves results in an approximately constant value of 150,000 cal./N for the soda-silica glasses.

The delayed elasticity process appears to be considerably more sensitive to composition than the process of viscous flow, as shown by the trend in activation energy.

(4) Relaxation Time

The relaxation time is that time necessary for the delayed elasticity to decay to $1/e$ of its original value, *i.e.*, to approximately 40%. That is, l becomes l_0/e and the equation reduces to

$$1/e = e^{kt},$$

from which t = relaxation time = $-1/k$.

This definition is essentially that given by Clerk Maxwell.

The calculated values of the relaxation times are given in Table V and shown graphically in Fig. 8.

TABLE V

RELAXATION TIME AS A FUNCTION OF TEMPERATURE

Temp. (°C)	Relaxation time (min.)	$10^3/T$
Glass SSC		
427.8	12.7	1.427
446.6	1.6	1.389
456.0	0.7	1.372
Glass X		
435.0	7.1	1.412
442.9	3.3	1.397
452.5	1.2	1.378
Glass No. 2		
427.7	19.2	1.427
442.2	4.8	1.398
446.8	2.6	1.389
452.5	1.5	1.378
455.9	1.2	1.372
Glass SS		
442.2	10.0	1.398
446.8	5.0	1.389
452.5	2.9	1.378
456.0	1.9	1.372
459.3	1.3	1.365
Glass No. 1		
442.4	100.0	1.398
447.0	59.0	1.389
452.5	28.6	1.378
456.0	17.2	1.372
459.3	9.1	1.365
466.0	3.7	1.353
471.2	1.9	1.344

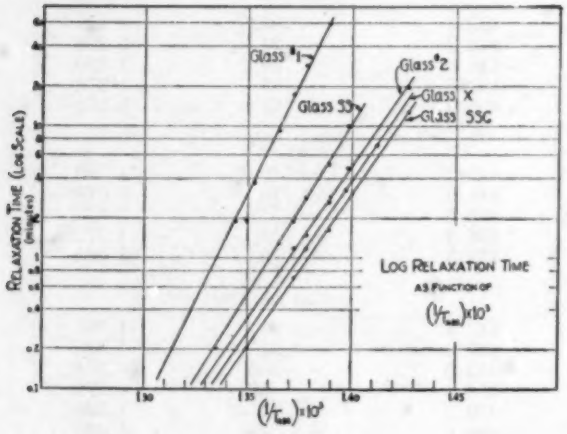

FIG. 8.

It is to be noted that for a given temperature the relaxation time increases considerably with increase of SiO_2 content; and, for any given relaxation time, the necessary temperature is higher as the SiO_2 content is increased.

The relaxation time may be compared qualitatively with the "half-life period" of radioactive decay, except that in this latter case the quantity is reduced to $1/2$ rather than $1/e$ of its original value.

It may readily be seen from an inspection of Fig. 8, which is a semilogarithmic plot, that at room temperature relaxation times will be of the order of millions of years. Consequently no soda-silica glass (within the range of composition

studied) can be considered stabilized at room temperature. On the other hand, at high temperatures where the viscosity is low, the relaxation times will be extremely short, very small fractions of a second, and only detectible by high-frequency electrical methods.

(5) Young's Modulus

Another striking feature, brought out in a previous investigation,[4] and verified herein, is the relation between Young's modulus and the temperature. Table VI contains the values of the modulus, E_1 (calculated from the instantaneous elastic elongation) and E_2 (calculated from the total elastic elongation).

TABLE VI

YOUNG'S MODULUS BASED ON INSTANTANEOUS (E_1) AND TOTAL (E_2) ELASTIC EXTENSION

Temp. (°C)	E_1	E_2
	Glass SSC	
427.8	3.8×10^3 kg./mm.^{2}	2.3×10^3 kg./mm.^{2}
446.6	2.7×10^3	2.1×10^3
459.0	2.2×10^3	2.2×10^3
	Glass X	
435.0	3.7×10^3	2.4×10^3
442.9	3.3×10^3	2.4×10^3
452.5	2.3×10^3	2.3×10^3
	Glass No. 2	
427.8	4.4×10^3	2.8×10^3
446.8	3.3×10^3	2.6×10^3
459.0	2.8×10^3	2.5×10^3
466.0	2.3×10^3	2.3×10^3
	Glass SS	
442.2	4.0×10^3	2.8×10^3
446.8	3.6×10^3	2.7×10^3
456.0	3.2×10^3	2.6×10^3
459.0	2.9×10^3	2.8×10^3
466.0	2.5×10^3	2.5×10^3
	Glass No. 1	
442.4	4.0×10^3	2.3×10^3
452.5	3.7×10^3	2.4×10^3
459.0	3.1×10^3	2.3×10^3
471.0	2.8×10^3	2.3×10^3

A study of Table VI verifies the observation that Young's modulus depends upon the time. If the delayed elasticity be taken into consideration, it appears that the value of Young's modulus is independent of the temperature. It will be noted that the two calculated values of Young's modulus become equal at the higher temperatures where there is no apparent delayed elasticity.

VIII. Discussion of Results

The "transformation points" of a comprehensive series of sodium metasilicate-silica glasses have been reported previously by Turner and Winks[13] and by Seddon, Tippet, and Turner.[12] The observed discontinuities were based on dynamic methods. The glasses of the present investigation are closely related in composition to several of those used in the experiments noted above. When the delayed elasticity is taken into consideration in viscosity calculations, however, a plot of $\log_{10}\eta$ against $1/T$ shows no discontinuity at temperatures near the "transformation point" for the various glasses.

The apparent disappearance of the delayed elastic effect at temperatures near the "transformation point" indicates that for every glass there exists a temperature at which and above which equilibrium rearrangements can be rapidly attained. Below this temperature the lag, or time element, becomes evident, its effect being more pronounced the lower the temperature. This is shown by the markedly lower values of the rate constants and the longer relaxation times as the temperature is lowered. The "transformation point" is, therefore, merely that temperature at which equilibrium is established rapidly.

The parallelism in $\log_{10}\eta$ against $1/T$ curves indicates that the process of viscous flow is controlled by some factor common to the series of glasses. Logically, the controlling factor would seem to be the rupture of the weakest link in the structure. If the random network hypothesis be accepted, the weakest bond is the Na–O. It is postulated that the viscous flow is governed by the series of Na–O bond ruptures proceeding at a rate characteristic for the applied load and for the temperature of test and resulting in an irreversible displacement.

The instantaneous elastic effect is probably due to an elongation of the framework as a whole. As the temperature of test is raised, a larger fraction of total elastic elongation can be observed instantaneously, because of the increased thermal agitation. Finally, at temperatures near the so-called "transformation point," the elastic distortion is effectively all instantaneous. This accounts for the approach of Young's "instantaneous" modulus to the value calculated on the basis of total elastic distortion.

The delayed elastic distortion appears to be

[13] W. E. S. Turner and F. Winks, "Thermal Expansion of Sodium Metasilicate-Silica Glasses," *Jour. Soc. Glass Tech.*, **14**, 110 (1930); *Ceram. Abs.*, **9** [9] 721 (1930).

more sensitive to composition than the viscous-flow process. This is shown by the increased slope of the $\log_{10} k$ *vs.* $1/T$ curves as higher SiO_2 contents are encountered. The data on relaxation time also show the effect of composition.

Reference has been made to findings of Seddon, Tippet, and Turner[12] that plots of log specific resistance against $1/T$ for several soda-silica glasses were approximately parallel. The activation energy (2.303 RA) for conduction is 25,000 to 30,000 calories per mol, that is, per Avogadro number of elementary processes. From our viscosity data we find activation energies of about 150,000 calories per mol. These bear a 1:6 or 1:5 ratio. Since the elementary process in conduction in all probability is the "breaking" of a Na–O bond to permit movement of Na^+ toward the cathode, we may perhaps conclude that the elementary process in viscous flow involves the coöperation of 5 or 6 such "breaks" more or less simultaneously. The possibility of such a coöperative effect was mentioned in the paper of Taylor, McNamara, and Sherman.[4]

IX. Summary

Using an experimental method employed by Lillie and other investigators, elongation rate data have been obtained on several soda-silica glasses subject to longitudinal tension at temperatures in the annealing range. These glasses were stabilized, that is, their properties had reached a steady state prior to testing. The data have been analyzed into the following simultaneously occurring elastico-viscous effects: (1) instantaneous elastic distortion, (2) delayed elastic distortion, and (3) pure viscous flow. Under isothermal conditions, the equation for the whole elongation at any instant is expressed by

$$E_t = I + l_v(1 - e^{kt}) + k_v t.$$

Viscosity coefficients have been evaluated for these glasses in the range 10^{11} to 10^{13} poises. The temperature coefficients of viscosity lead to an activation energy of about 150,000 cal. per mol, for each glass. A comparison of this quantity with that for electric conductivity on these glasses (18,000 cal./mol) indicates that a cooperation of about 8 times as many Na–O bonds to be "broken" in viscous flow as in electric conduction must occur.

For the delayed elastic process, the rate of stress release is proportional to the stress, as suggested by Clerk Maxwell. The rate constants have been evaluated and also their reciprocals (the "relaxation times"). The temperature coefficients of these rate constants lead to activation energies of 105,000 to 150,000, the higher energies being for glasses higher in silica.

Values of Young's modulus of elasticity have been computed from the instantaneous distortion and from the total elastic distortion. While the former decreases with rising temperature, the latter appears to be independent of temperature in the range studied. This was found to be the case in the Na_2O–CaO–SiO_2 glass studied by Taylor, McNamara, and Sherman.[4]

The results of the investigation indicate that the so-called "transformation point" is merely the temperature at which internal equilibrium is rapidly established. There appears to be no discontinuity in properties between a viscous liquid and a stabilized glass.

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EFFECT OF HEAT TREATMENT ON THE THERMAL EXPANSION OF SOME SILICA-ALUMINA GLASSES*

By C. L. Thompson and C. W. Parmelee

Abstract

Glasses made from Florida kaolin and quartz so that the compositions lie in the field in which mullite is the primary phase showed characteristic changes in their thermal expansion when heated. These may be due in part to stresses in the glass and in part to the crystallization of submicroscopic mullite.

Cristobalite or tridymite also crystallized from the glasses when they were heated to 1230°C.

I. Introduction

(1) Purpose

The investigation was undertaken to determine the effect of varying heat treatment on the thermal expansion characteristics of glasses composed chiefly of alumina and silica.

II. Experimental

(1) Preparation of Glasses

The glasses were compounded from fine quartz that was separated by water sedimentation from Ottawa (Illinois) quartz flint and "EPK" brand Florida kaolin. The raw materials were mixed as a slip, dewatered in small plaster vats, and dried.

The compounded mixtures were fused to glasses in covered Alundum crucibles in a gas-fired Volcano furnace and cooled from the maximum temperature by quenching in water. In all cases, an attempt was made to use a temperature approximately 50°C above the liquidus temperature of the mixture. The fusions were ground and re-fused two or three times, until microscopic examination showed them to be free from crystals and of a fair degree of homogeneity.

(2) Chemical Analyses

The silica content of each glass was determined by using a sodium carbonate fusion to decompose the glass, a single dehydration of the silica with perchloric acid, and volatilization of the silica with hydrofluoric acid. The R_2O_3 content of several of the glasses was determined by using a double precipitation of the hydroxides in the customary manner.

(3) Thermal Expansion

The thermal expansions of the glasses were determined by the Fizeau-Pulfrich interferometer method. In most cases, four determinations were made on each glass, using (*a*) the water-quenched sample, (*b*) the same specimens without removing them from the thermal expansion furnace, (*c*) the same specimens after they had been held at a temperature of 1000° ± 30°C for 44 hours, and (*d*) other specimens that had been held at 1000° ± 30°C for 115 hours.

Expansion determinations from room temperature to 300°C were also made on several samples that had been heated at 1130° ± 20°C and 1230° ± 20°C for 20 hours.

(4) Specific Gravity

The specific gravity of each water-quenched specimen was determined by the standard method of the American Ceramic Society. The specific gravities of several of the specimens, after heat treatment at 1000°C, were calculated from the specific gravities of the water-quenched samples, and the amount of permanent shrinkage caused by the heat treatment. The linear changes were measured on specimens approximately 0.5 centimeter long with micrometer calipers.

(5) Microscopic Examinations

The index of refraction of each water-quenched sample and each sample heat-treated at 1000°C was determined by the oil immersion method. Samples that were heated to higher temperatures were examined for visible devitrification.

(6) X-Ray Examination

Diffraction patterns were obtained from several samples, both quenched and after heating at 1000°C, and from glasses No. 2 and No. 5 after 20 hours heat treatment at 880°C and 930°C.

* Presented at the Thirty-Eighth Annual Meeting, American Ceramic Society, Columbus, Ohio, March 31, 1936 (Refractories Division). Revised copy received April 26, 1937.

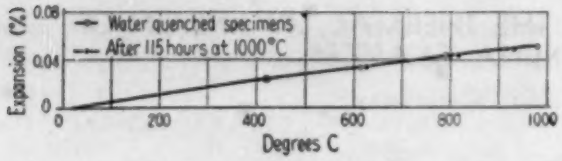

FIG. 1.—Glass No. 1.

III. Results

(1) Statement of Results

(*a*) *Chemical Analyses:* The partial analyses of the glasses are given in Table I. In addition to alumina and silica, they contained impurities ranging from about 0.3% for the most siliceous to 1.3% for the most aluminous. These values for impurities were calculated from typical compositions of the raw materials and included iron oxide and titania, which were also included in the determined R_2O_3 values.

TABLE I

Glass No.	1	2	3	4	5	6	7
SiO_2(%)	95.1	91.2	87.1	83.1	78.5	73.6	65.9
R_2O_3(%)	5.1	n.d.	13.1	17.1	n.d.	n.d.	33.8

(*b*) *Thermal Expansion:* Typical thermal expansion curves are shown in Figs. 1 to 4, inclusive.

It will be noted that on the first run of the quenched specimens, expansion ceased at a temperature ranging from 700° to 800°C and

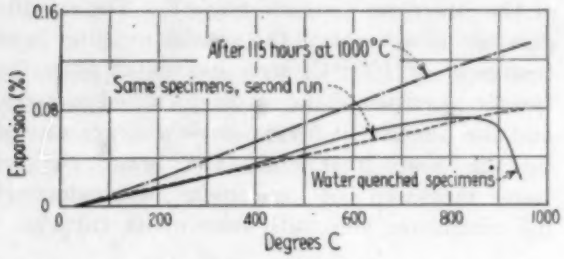

FIG. 2.—Glass No. 3.

shrinkage began at a higher temperature, except for the most siliceous glass. During the second run, the same specimens expanded at a uniform rate to a higher temperature than during the first test. Specimens that had been heated to 1000° ± 30°C for 115 hours had almost 50% greater expansion than the water-quenched samples and did not shrink when heated to 980°C, but they had a slightly smaller rate of expansion above 900°C than at lower temperatures.

All compositions, with the exception of the most siliceous one, exhibited these changes. The temperature at which shrinkage first began increased with the silica content until it was 925°C for sample No. 2. In all of the more siliceous samples, the expansion below 700°C was greater during the first heating than during the second, but the reverse was true for the two samples having lower silica content. The temperature at which shrinkage began for the second run was not reached for three samples, but these samples showed permanent shrinkage when heated

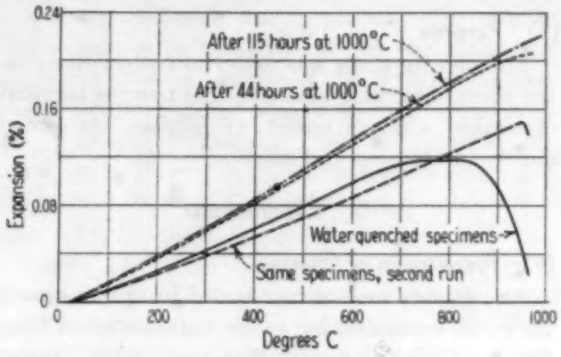

FIG. 3.—Glass No. 5.

44 hours at 1000°C. The temperatures at which shrinkage began are given in Table II.

Samples of the glasses that were tested after 20 hours heat treatment at 1230° ± 20°C showed the typical tridymite or cristobalite discontinuity in their thermal expansion curves, and the silica devitrification that had occurred during the heat treatment was apparent from microscopic examination. Other samples that were heated for the same length of time at 1130° ± 20°C showed no discontinuity in their expansion curves and appeared completely glassy under the microscope. Curves are shown in Fig. 5.

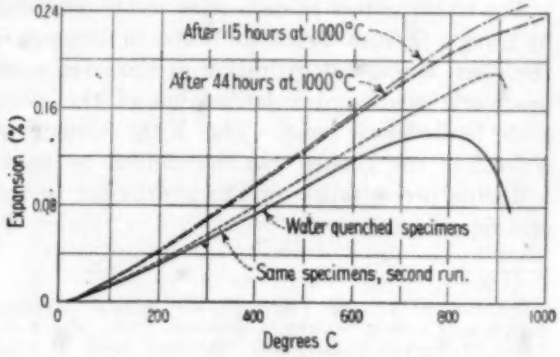

FIG. 4.—Glass No. 6.

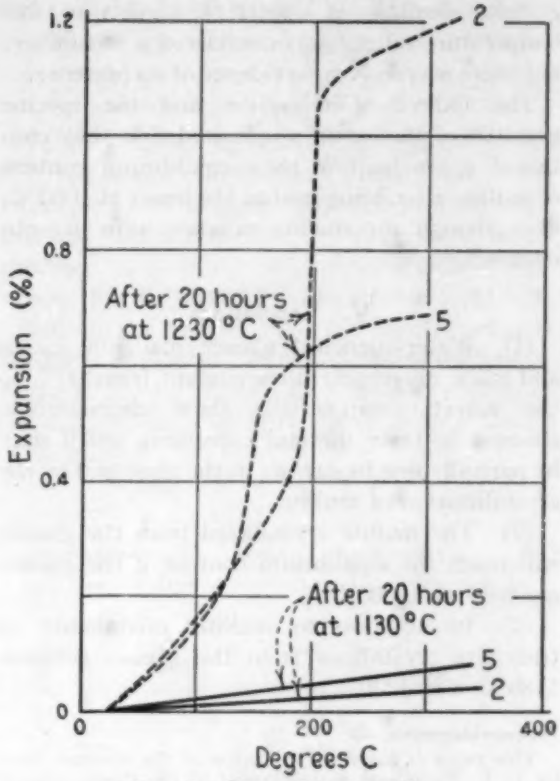

FIG. 5.—Glasses No. 2 and 5.

(*c*) *True Specific Gravity:* With increases in alumina, the true specific gravities of the glasses, after heat treatment at 1000°C, showed a progressive increase as compared with those of the water-quenched glasses. This is shown graphically in Fig. 6.

TABLE II

TEMPERATURES AT WHICH GLASSES BEGAN SHRINKING

Glass No.	First Run (°C)	Second Run (°C)
2	925	Above 960
3	860	" 945
4	825	" 925
5	825	At 950
6	820	" 900
7	820	" 885

(*d*) *Microscopic Examination:* The indices of refraction of the glasses after heat treatment at 1000°C showed increases similar to the increases in specific gravity, but the values were slightly erratic (Fig. 6). These heat-treated specimens, when examined under a magnification of 720 diameters, were apparently completely glassy.

All compositions, after twenty hours heating at 1130° ± 20°C, were also apparently completely glassy, while after heating for the same time at 1230° ± 20°C, silica devitrification was evident.

(*e*) *X-Ray Examination:* The water-quenched glasses gave the broad, diffuse line that is characteristic of amorphous materials, but samples that had been heated for 115 hours at 1000°C gave a mullite pattern and a less intense amorphous line. The mullite lines were broad since the crystals were submicroscopic, but the number and intensity of the lines indicated considerable crystalline material. Only glasses No. 2 and No. 5 were X-rayed after heat treatment below 1000°C; a mullite pattern was obtained from glass No. 5 after 20 hours heating at 930°C but not after the same time at 880°C. Glass No. 2 gave only the amorphous pattern in both cases.

(2) Accuracy of Measurement

(*a*) *Chemical Analyses:* Duplicate determinations were made, and the results were required to check within the limits specified by the American Society for Testing Materials, except in the R_2O_3 determinations for samples No. 1 and No. 7, which are the results of single determinations.

(*b*) *Thermal Expansion:* The accuracy of the thermal expansion data, with the exception of the samples heated to 1230°C, was less than usual with ceramic materials because of the low expansion of the samples and the resulting small

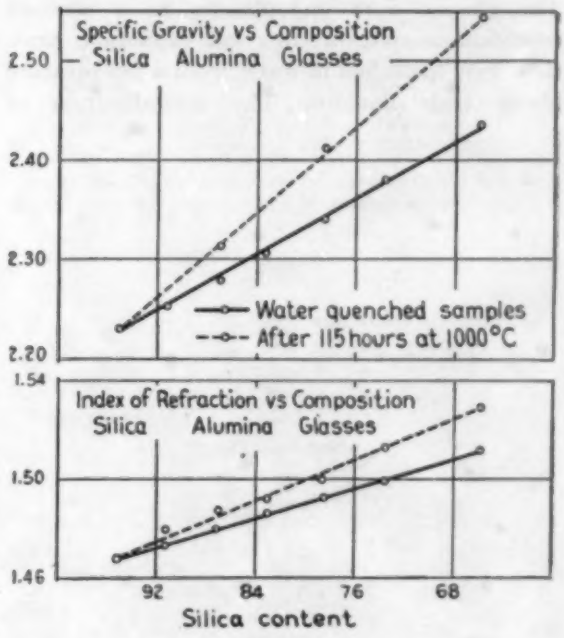

FIG. 6.

number of interference fringes passing during a test. The probable accuracy ranges from about ±5% for sample No. 1 to ±2% for sample No. 7.

(*c*) *Index of Refraction:* The accuracy of the determination of index of refraction was ±0.003.

IV. Discussion of Results

The X-ray patterns showed that the glasses whose compositions lie on the alumina side of the eutectic in the alumina-silica system contained sufficient crystalline mullite to give a well-developed diffraction pattern after they had been heated at 1000°C for 115 hours. It is to be expected, of course, that such compositions would devitrify to mullite and cristobalite at some temperature below 1551°C. The negative expansion shown by the expansion curves suggests that the mullite crystallization may have begun at a considerably lower temperature, but the lowest temperature for which mullite crystallization was definitely established in the two glasses that were X-rayed after heat treatment below 1000°C was 930°C for glass No. 5. There are two possible explanations for the negative expansion shown in the expansion curve of the water-quenched specimens at a temperature lower than that at which a mullite diffraction pattern was obtained, *viz.*, (1) that the shrinkage was due to the formation of crystal nuclei that were too small to diffract X-rays and (2) that the shrinkage was due to the relieving of stresses. The glasses were undoubtedly in a stressed condition in spite of their low expansion, since they were quenched in water from a temperature above their liquidus. The crystallization of gamma alumina, as occurs in kaolins in this temperature range,[1] was considered a possibility, but there was no X-ray evidence of its presence.

The indices of refraction and the specific gravities of the samples indicated that they contained approximately their equilibrium content of mullite after being heated 115 hours at 1000°C, even though the mullite crystals were of submicroscopic size.

V. Conclusions

(1) Water-quenched glasses made of kaolin and silica ranging in silica content from 66% to the eutectic composition show characteristic changes in their thermal expansion which may be partially due to stresses in the glass and to the crystallization of mullite.

(2) The mullite crystallized from the glasses will reach the equilibrium content if the glasses are held at 1000°C.

(3) In addition to mullite, cristobalite or tridymite crystallizes from the glasses between 1130°C and 1230°C.

Acknowledgments

This paper is based on a portion of the research done by C. L. Thompson in fulfillment of the thesis requirement for the degree of Doctor of Philosophy in Engineering in the Graduate School of the University of Illinois. The authors wish to acknowledge their indebtedness to G. L. Clark, Professor of Analytical Chemistry, University of Illinois, for the use of the X-ray equipment of his laboratory.

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[1] Herbert Insley and R. H. Ewell, "Thermal Behavior of the Kaolin in Minerals," *Jour. Research Nat. Bur. Stand.*, **14** [5] 615–27 (1935); R.P. 792; *Ceram. Abs.*, **14** [8] 201 (1935).

PHYSICAL CHARACTERISTICS AND PROPERTIES OF TEXTILE MATERIALS MADE FROM GLASS*

By John H. Thomas

Table I shows representative figures on the first 100 hours of a life-time test on one of the filter cloths. This cloth was under test 200 hours and was removed at the end of that period for inspection. Two hundred hours is, in many cases, normal life for a filter cloth. These tests were conducted on a small Oliver filter with 1/3 square yard area simulating actual operating conditions. Table II gives a tabulation of flow rates obtained through various glass filter cloths under 25 inches of mercury.

Table I

Total running time (hr.)	Vacuum in. mercury	Solids in slurry (%)	Moisture in cake (%)	Blow-back (lb.)	Grams cake/ 1/10 sq.ft.	Cake yield/ 24 hr. (lb.)	Efficiency (%)
2	23	32.25	23.94	20	70	554.40	99.5
10	20	32.60	30.20	52	60	475.00	99.4
18	21	36.36	26.51	36	61	483.12	99.1
26	22 1/4	36.40	22.50	30	69	546.48	99.3
34	21	37.50	25.85	34	66	522.72	99.3
40	20 1/4	39.00	25.60	32	67	530.64	99.6
46	21 1/4	40.00	27.60	36	76	601.92	99.6
54	21	40.35	26.65	36	72	570.24	99.4
62	20 3/4	41.10	26.70	35	85	673.20	99.6
69	20 1/2	44.00	25.23	35	83	657.56	99.6
77	20 1/2	42.60	26.20	35	79	625.68	98.9
83	20	44.10	25.90	35	80	633.60	99.7
91	21	41.80	25.30	37	74	587.00	99.4
99	21	41.00	26.48	35	75	594.00	98.8
107	21 1/4	41.00	26.80	30	79	625.68	99.5

Table II

Cloth No.	(In.²·H_2O·min.·in.² 6 = in. head)	Cloth No.	(In.²·H_2O·min.·in.² 6 = in. head)
4A	231	1110	140
110	340	1110A	115
120	185	1120	36
121	128	1130	52
130	189	1131	94
140	149	1140	61
150	228	1141	95
160	120	1150	417
170	476	1151	432
180	144	1152	486
180A	106	1153	398
190	58	1183	172
190A	110	1240	190
1100	61	1241	295
1100A	54	1242	476

Table III gives a tabulation of tests run to determine the action of acids on glass filter cloths. These tests were run in two ways, (1) the cloth was treated with the acid and a test was taken of the tensile strength while still wet, and (2) a similar piece of cloth was treated in the same acid bath, but, following the acid bath, it was dried, and then the tensile strength test was run after fuming on an extremely small percentage of a lubricating oil to prevent the fibers from mutually scratching each other during the test. The conclusions at hand (although not definite as more work is being conducted along these lines), appear to be that the acids increase the strength of the cloths, but that the removal of the lubricating oil allows

Table III

Cloth	Water	H_2SO_4	HNO_3	HCl	Original strength (lb./sq. in.)
1131	230	486	187	430	325
1100A	225	434	185	181	192
1140	209	400	380	327	270
160	198	240	258	220	188
1152	185	261	168	246	243

The cloths were held at 180°F for one hour in 50% concentrations of the acids indicated; they were then washed and dried over night; the strengths indicated above are averages of several tests.

Table IV

Material	Thickness (in.)	Breakdown voltage/ mil	Impregnation
Glass	0.009	1190	Methacrylate
"	.007	1170	Tornesit
"	.018	582	1202 Glyptal
Cotton	.023	424	1202 Glyptal
Cambric	.007	897	
Asbestos	.025	128	Glyptal
"	.025	73	1202 Glyptal

These tests were conducted by the short-time dielectric strength test for tapes (A.S.T.M. designation D149–36T).

Table V

Material	Description	Minimum break (lb.)
Asbestos (0.025 × 1)	80% asbestos; 6% iron	45
Glass (0.010 × 1)	Class A	136
Glass (0.005 × 1)	Class A	127
Glass (0.015 × 1)	Class A	280

	Insulation Resistance			
Material	45% humidity	74.5% humidity	90% humidity	Temperature (°F)
Asbestos (0.025 × 1)	0.75 megohm	0.225 megohm	0.005 megohm	100
Glass (0.015 × 1)	2000 "	10 "	0.325 "	100

* Presented at the Thirty-Ninth Annual Meeting, American Ceramic Society, New York, N. Y., March 23, 1937 (Glass Division). Six tables and two figures are presented here; for text material see *Glass Ind.*, **18** [6] 201 (1937).

for scratching of the individual fibers during test, giving results apparently lower.

As yet it is not practicable to use glass cloth under alkaline conditions. Development of suitable glass compositions, however, is going forward, and it is expected that soon glass cloth can be recommended for use under all conditions.

A number of tests have been made with various impregnating materials to determine the limits at which impregnated tapes and yarns can be used. Table VI gives data on the temperatures which can readily be withstood by various impregnations.

FIG. 1.—Cotton fibers. ×400.

FIG. 2.—Glass textile fiber. ×400.

TABLE VI

Material	Impregnation	250°F (65 hr.)	350°F (200 hr.)
Asbestos	1201 Glyptal	Splits	Will not stand handling
Glass	1201 "	Good flexibility	Splits
"	Methacrylate	Fair flexibility	Retains flexibility
"	Tornesit		Destroyed by heat
"	G.E.W.L. 472	Good flexibility	Retains flexibility

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SOME CHARACTERISTICS OF STEATITE BODIES*

By L. E. Thiess

Abstract

A discussion is given of the characteristics of vitrified steatite bodies containing more than 70% talc. Several typical compositions have been selected from a series of experimental bodies and their firing range and other ceramic and physical properties are described.

I. Introduction

Steatite bodies may be divided into two groups, (1) bodies which are more or less porous such as electrical refractories,[1] and (2) vitrified steatite bodies which contain over 70% soapstone or talc.

II. Definition

Schwandt[2] has given the following definition of steatite bodies:

"All materials are called 'steatite' if they contain from 70 to 90% soapstone or talc. After firing, they show a uniform structure of magnesium-silicate crystals."

In a recent paper on electrical insulation materials, Steger[3] gives a similar definition.

"Steatite bodies contain talc or soapstone, *i.e.*, a natural hydrated magnesium-silicate as the principal constituent, with an addition of feldspar and clay."

Albers-Schoenberg[4] describes steatite as being composed of at least 70% talc, the remainder consisting of such substances which bring about complete vitrification by eutectic melts and crystallization. The finished product consists of a densely felted structure of a magnesium metasilicate.

III. History

In 1912, the first composition of steatite bodies was published[5]; the body highest in talc content was 70% talc, 25% ball clay, and 5% flint.

The firing temperature was given as cones 6 to 7. This body is still porous at high temperatures, and therefore cannot be considered as true steatite.

Singer[6] published a description of steatite insulators, together with data on electrical and mechanical properties.

IV. Raw Materials—Compositions—Firing

Considering the high amount of talc used in such bodies, it is obvious that a careful selection of this mineral must be made. Talcs high in lime (CaO), those with a flaky or foliated structure, or those which do not develop plasticity on wet grinding are unsuitable.

V. Experimental

The following three compositions were chosen from a series of 20 bodies, ranging from 70 to 85% talc.

Table I

Steatite Bodies

	No. 8 (%)	No. 12 (%)	No. 13 (%)
California talc	86	85	82
English ball clay	10	13	12
Potash feldspar	4	2	6

Table II

Chemical Analyses of Steatite Bodies

	German steatite	German steatite*	Calculated bodies No. 8 (%)	No. 12 (%)	No. 13 (%)
SiO_2	64.13	66.08	63.6	63.5	63.4
MgO	28.64	27.32	28.5	28.1	27.3
Al_2O_3	5.89	5.13	5.7	6.4	6.7
Alkalis (Fe_2O_3, etc.)	1.60	1.72	2.2	2.0	2.6
Total	100.26	100.25	100.0	100.0	100.0

The chemical compositions of bodies Nos. 8, 12, and 13, were calculated from the analyses of the raw materials.

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* Received February 25, 1937.

[1] L. E. Thiess, "Steatite Bodies for Ceramic Heating Units" (Speicksteinmassen für keramische Heizkoerper), *Sprechsaal*, **65** [30] 549–52 (1932); *Ceram. Abs.*, **11** [11] 575 (1932).

[2] E. Schwandt, Construction Materials for High Frequency Applications (Baustoffe für Hochfrequenztechnik) pp. 120–37. Published by Hachmeister & Thal, Leipzig, 1930.

[3] W. Steger, "Steatite," *Electrotech. Z.*, **57** [17] 471–76 (1936).

[4] E. Albers-Schoenberg, "Insulation Materials of the Steatite Group" (Isolierstoffe der Steatitgruppe), *ibid.*, **54** [23] 545–47 (1933); *Ceram. Abs.*, **13** [10] 267 (1934).

[5] Anon. Question Box, *Sprechsaal*, **45** [5] 78 (1912).

[6] F. Singer, Ceramics in the Service of Industry and Economics (Die Keramik im Dienste von Industrie und Volkswirtschaft), pp. 395–407. Vieweg & Sohn, Braunschweig, 1923; *Ceram. Abs.*, **2** [10] 233 (1923).

* H. M. Kraner and R. A. Snyder, "Mechanical and Thermal Shock Test on Ceramic Insulation Materials," *Jour. Amer. Ceram. Soc.*, **14** [9] 617–23 (1931); Table II, p. 621.

The experimental bodies were ground with water in ball mills. It was noted that wet grinding develops a better plasticity than blunging. Owing to the comparatively small amount of clay permissible in such bodies, it is obvious that they do not possess the same degree of plasticity and dry strength as the average whiteware bodies; therefore, organic binders, such as gum arabic, dextrine, etc., are sometimes added to improve their workability. Endell, Fendius, and Hofmann[7] have investigated the effect of bentonite on porcelain and steatite bodies. Experiments made by the writer showed that the plasticity and dry strength are considerably increased by small additions of bentonite without affecting other properties, such as shrinkage, firing range, color, etc.

Steatite insulators are manufactured by the wet process (plastic) method, by dust pressing, and by casting. In dry-process bodies, a certain percentage of the talc is calcined to reduce the shrinkage and prevent sticking to the dies. The softness and the nonabrasive character of the steatite dust causes very little mold wear and makes such bodies an ideal material for automatic pressing.

VI. Glazing and Firing

The temperature to which steatite bodies are fired varies from cones 10 to 14. The firing is done either by the one-fire method (high bisque firing) or by the two-fire method (low glost firing). There are also instances where steatite pieces are first fired approximately to 1000°C to make them strong enough for drilling and tapping or other finishing operations. The final firing is made at cones 10 or 14.

Two fritted glazes gave satisfactory results for glost firing. Glaze A was fired to 950°C and glaze B to 960°C.

Glaze A

$$\left.\begin{matrix}0.210\ Na_2O\\0.290\ CaO\\0.500\ PbO\end{matrix}\right\}\ \left.\begin{matrix}0.184\ Al_2O_3\\0.340\ SnO_2\end{matrix}\right\}\ \{2.50\ SiO_2$$

Glaze B

$$\left.\begin{matrix}0.317\ K_2O\\0.683\ PbO\end{matrix}\right\}\ \left.\begin{matrix}0.131\ Al_2O_3\\0.230\ SnO_2\end{matrix}\right\}\ \{2.39\ SiO_2$$

[7] K. Endell, H. Fendius, and U. Hofmann, "Base Exchange of Clays and Molding Problems in Ceramics" (Basenaustausch von Tonen und Formgebungsprobleme in der Keramik), *Ber. deut. keram. Ges.*, **15** [12] 595–625 (1934); *Ceram. Abs.*, **14** [6] 149 (1935).

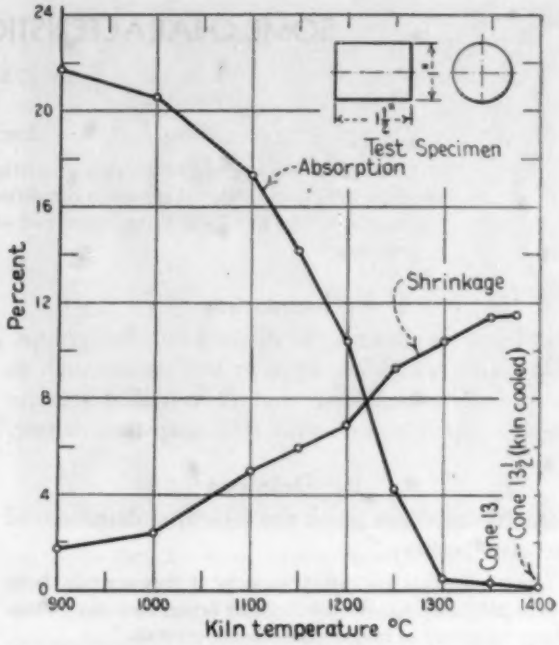

FIG. 1.—Draw trials on steatite body No. 8; firing shrinkage and water absorption.

A series of high-fire glazes (cones 12 to 13) was also made up as follows:

$$\left.\begin{matrix}0.446\text{–}0.539\ MgO\\0.122\text{–}0.233\ K_2O\\0.266\text{–}0.339\ CaO\end{matrix}\right\}\ 0.387\text{–}0.517\ \left\{\begin{matrix}Al_2O_3\\3.67\text{–}4.30\ SiO_2\end{matrix}\right.$$

+8% SnO_2 or a zirconium silicate as opacifier.

Most of these glazes gave a smooth, white opaque surface, with some showing excellent mechanical strength.

In Fig. 1, a shrinkage-absorption diagram of body No. 8 is shown which is typical for all similar compositions. The test pieces consisted of extruded cylinders, $1^1/_2$ inches long and 1 inch in diameter. Draw trials from 900° to 1350°C were made. One set of test pieces was left in the kiln to cool to room temperature.

Talc bodies have a short firing range, especially those which contain about 50% clay. In such bodies, the vitrification and fusion temperatures are close together (MgO–Al_2O_3–SiO_2 eutectic at 1345°C). The steatite bodies high in talc and low in clay have a firing range of $1^1/_2$ to 2 cones, which is sufficient for firing in closely controlled periodic or continuous kilns.

A cone-fusion test was made on a series of six steatite bodies, ranging from 80 to 85% talc, 9 to 17% plastic kaolin, and 2 to 10% feldspar. At cone $12^1/_2$ all bodies are still porous; at cone 14 most of them are vitrified; at cone 15 five of the

bodies are fused; at cone 16 only a slag of each body is left in the cavity of the fireclay support.

A thorough study of the chemical, physical, and structural changes in talc at different temperatures was made by Krause.[8]

He found that when talc is heated above 1000°C a steady growth of clinoenstatite ($MgO \cdot SiO_2$) and cristobalite crystals takes place.

VII. Mechanical and Electrical Properties

The modulus of rupture of steatite bodies Nos. 8, 12, and 13, when fired to different temperatures, is shown in Fig. 2. The test pieces were unglazed

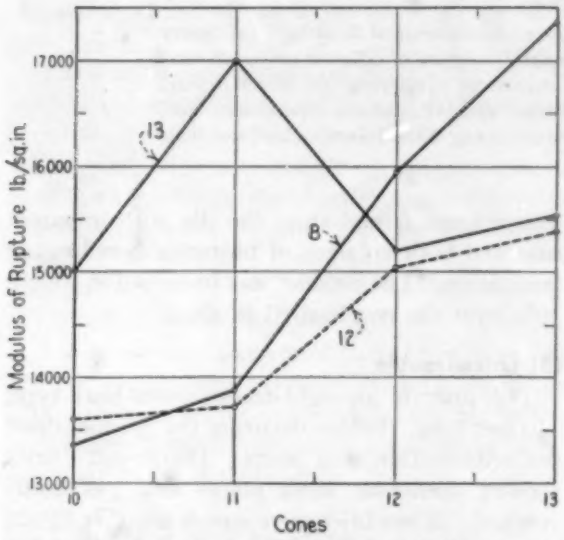

FIG. 2.—Mechanical strength of steatite bodies Nos. 8, 12, and 13 when fired to different cone temperatures.

cylinders 1 inch in diameter and 7 inches long, which were broken on a transverse testing machine over 5-inch supports.

Recent tabulations of electrical and mechanical properties have been given by Albers-Schoenberg,[4] Handrek,[9] and Thurnauer.[10] The greater toughness of vitrified steatite bodies is explained by the fact that these bodies consist chiefly of crystalline material (magnesium-silicate), while electrical porcelain and especially those fired at lower temperatures consist of from 40 to 60% glass (feldspar-silica glass) and crystalline materials, such as mullite and undissolved quartz.

The coefficient of linear thermal expansion of vitrified steatite varies from 7.5 to 8.5 $\times 10^{-6}$. These values are considerably higher than for electrical porcelain. Therefore, vitrified steatite bodies are more sensitive to thermal shock, and the cooling of the ware, especially shapes with heavy walls, must be carried out with greater care. It was also found that steatite insulators developed cooling cracks and failure when hot lead alloys, used for connecting pins, caps, etc., were poured in holes, as is the practice with certain types of porcelain insulators.

[8] Otto Krause, "Ceramic Magnesium-Silicates" (Über Keramische Magnesiumsilikate), *Ber. deut. keram. Ges.*, **10** [2] 94–104 (1929); *Ceram. Abs.*, **8** [9] 666 (1929).

[9] H. Handrek, "Ceramic Insulation Materials for High Frequency" (Keramische Isolierstoffe für Hochfrequenz), *Z. Ver. Deut. Ing.*, **78** [50] 1441–49 (1934).

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(5) Anon., "Occurrence of Talcs and Their Use" (Über das Vorkommen v. Talk und Seine Verwendung), *Keramos*, **8** [24–25] 919–26 (1929); *Ceram. Abs.*, **9** [5] 362 (1930).

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PRACTICAL DE-AIRING*

BY JOHN H. ISENHOUR

ABSTRACT

The following points are discussed in this paper: (1) theoretical de-airing: (*a*) theory of colloids, (*b*) effect of de-aired material on metal, (*c*) nature of different materials relative to de-airing, (*d*) unequal density, and (*e*) lamination; (2) drying: (*a*) rate of drying, (*b*) drying strength, and (*c*) shrinkage; (3) firing; and (4) practical experiments with de-airing from the machine to the finished product, using three different clays and their combinations.

I. Introduction

(1) Material Worked

A fine-grain decomposed shale-schist of low plasticity is difficult to form. It has approximate drying and firing shrinkages of 7% and 3%, respectively. Its firing range for good red color is from cones 5 to 7.

(2) First Trial Operation

From a 6-foot pug mill, the clay was forced through a sealing chamber to a second auger that forced it through a hollow die to a shredder. From the shredder, inside a $3^1/_2$-foot vacuum chamber, pugging knives fed the material to a single pickup auger. Three feet of spiral auger, 13 inches in diameter, fed to a double-wing auger. The double-wing auger had an approximate 20-degree taper with a straight discharge. The die was a standard oil-lubricated brick die with an 8-degree curved taper on the sides and a curved taper approximating 20 degrees on top and bottom. The die was 10 inches in length with a 4-inch spacer between auger and mouth of die.

The speed of the auger for first operation was 25 r.p.m. Production was 100 brick per minute and 5000 per hour. A vacuum of 28.5 to 29 inches was maintained with a rotary pump.

Brick were made with 3 holes on the center line. The column flowed from the die with apparent ease and with no signs of blistering, swelling, or lamination. The product was increased in weight 10% over the nonde-aired product.

(3) Drier Trouble

The drier is an eight-track, waste-heat type, 110 feet long. Before de-airing the product dried perfectly in thirty-six hours. The de-aired brick showed numerous weak places and was badly cracked. If two brick were struck together lightly they would fall into six or eight pieces. The individual pieces had great strength.

The time of drying was increased to 48 hours and finally to 60 hours. The drier temperature was decreased, but the trouble remained.

II. Undue Compression before Clay Reaches the Die

The tapered auger was removed and a double-wing straight auger was put on with the same diameter and pitch as the spiral knives behind it. With this change, the drier loss was completely eliminated. The original tapered auger apparently compressed the de-aired mass to much and produced slick-sided nodules that would not bond together properly in the die.

III. Fired Product Defects

After the drier trouble was apparently corrected, the fired product showed losses of 40% or more. Some of the brick were brittle and glassy;

* Presented at the Annual Meeting, American Ceramic Society, Columbus, Ohio, March 31, 1936 (Structural Clay Products Division).

others were sound and had a clear ring. The poor brick did not come from any particular location in the kiln. A good brick might be on top or bottom and next to a poor one. From appearances one could not always judge the good brick from the poor ones, but when struck together the unsound brick would break into five or six pieces.

(1) Effect of Vacuum Variation

Different degrees of vacuum were tried from 5 to 29 inches. A vacuum of 10 inches or below did not give the desired workability for hollow ware or the desired density for brick; the vacuum from 10 to 25 inches increased cracking about 20%. A vacuum of 28½ to 29 inches produced the 40% loss.

The solid brick developed an S-crack in the center and every brick broke along this crack. Some were weak in other places. The S-shape of auger lamination was caused by two streams of clay flowing from the double-wing auger and never uniting sufficiently to knit the two streams together.

(2) Effect of Single-Wing Auger

A single-wing auger eliminated the S-crack but did not decrease the breakage of the brick in the kiln. The single-wing auger caused a strain on the auger shaft, making it impossible to keep the packing tight in the shaft bearing.

(3) Effect of Triple-Wing Auger

A triple-wing auger gave satisfactory extrusion since the material flowed through the dies with great ease, but the brick coming from the kilns were yet too brittle.

(4) Firing and Cooling Schedule Changed

While the machine experiments were in progress, the firing and cooling methods were changed. The water-smoking period was increased from 36 to 54 hours, and the cooling period was increased from 5 to 12 days, but there was no decrease in the loss.

IV. Experimentation on Dies

The bridge and cores for three holes were again placed in the die. Spacers up to 10 inches were placed between the augers and dies. The horsepower was increased about 5%, and the losses in the kilns were reduced to 20%. Many brick still showed lamination and weak ends. A new die, 10 inches in length with a 30-degree taper on all sides, was placed on the machine. The weak ends disappeared, but brittleness was not eliminated.

A die 12 inches in length with a 10-degree taper was then tried. The horsepower was increased another 5%, but this type of die did not improve conditions.

V. De-Airing or Evacuation

In many of the brick of weak structure, there appeared to be two types of clay where the brick broke, one much more de-aired than the other. This indicated nonuniform de-airing. The partially de-aired masses appeared to be sandwiched between two layers of dense material that had slipped on the nonde-aired material thus causing lamination and a disrupted bond on the column structure.

The speed of the machine was increased from 25 to 33 r.p.m. with the same output as before. This reduced the mass passing through the shredder one-third and permitted better evacuation. Difficulties were encountered, however, in the spiral pick-up auger. The single spiral pick-up auger gathered a full amount of clay on the bottom and less clay as it came to the top. This gave an unequal flow to the auger point, thereby causing a pulsating column. This column plus the constant auger speed resulted in "auger-slicks," one out of four brick showing "auger-slicks" and longitudinal cracks. Finally the knives and spiral pick-up augers were placed far enough from liners to allow the material to build up against the augers to assure uniform pick-up and, therefore, uniform flow.

With these changes, the loss in the finished product was decreased to 5%. It was never possible, however, to obtain uniform de-airing, and the best results were finally obtained only by a 20% increase in power consumption. After the final changes, hollow ware was extruded and processed with less than 2% total loss.

VI. Use of Short Shaley Schist

This material when ground and tempered was granular enough to permit much better evacuation and offered no difficulty in shredding.

With this material it was necessary to remove all of the die spacers and put on a die with practically a straight issue, 8 inches long with a 3-degree taper. The triple-wing auger was replaced with a double wing.

VII. Conclusion

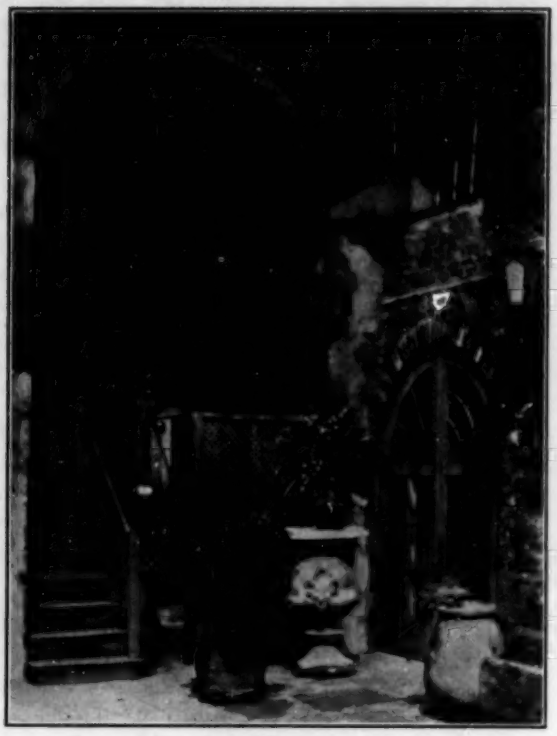
These experiments were completed in six months, and the results showed practically 100% improvement in face brick and hollow tile. The drying period has been reduced from 36 hours on the nonde-aired to 24 hours on the de-aired product.

The cooling period was increased from 4 days on nonde-aired to 6 days on the de-aired product.

The finishing pyrometric cone has been reduced from 7 to 4.

G. W. Isenhour & Sons
Salisbury, North Carolina

MAKE PLANS FOR THE 1938 (40TH) ANNUAL MEETING IN NEW ORLEANS, MARCH 27—APRIL 2



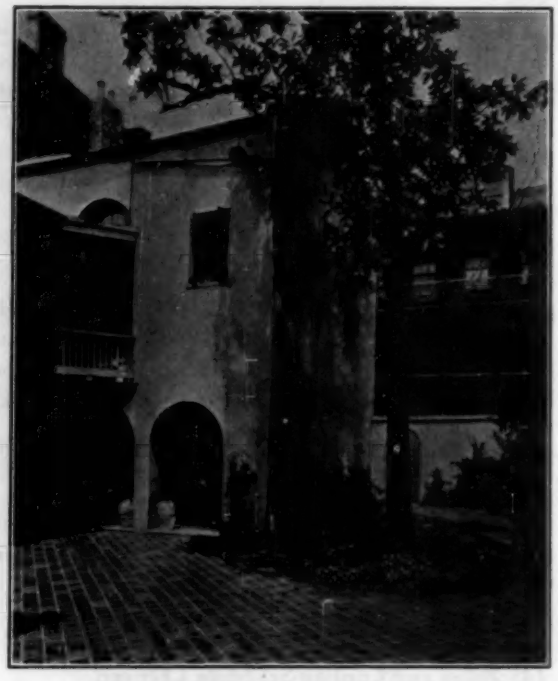
Courtyard, New Orleans Vieux Carre

Nearly all the old homes in the New Orleans Vieux Carre have their courtyards or patios.

To the French the flagged or brick "backyard" was a court, but with the coming of the Spanish the term "patio" was used and remained in favor. Most of the patios have fountains in the center and a well-planned garden.

Huge wide-mouthed, pot-bellied earthen jars that had carried overseas the oil from the olive groves of Spain found their way into the gardens and were used to catch the rain water from the gutters and downspouts.

Occupying one or two sides of the court are the kitchen and slave quarters, buildings always detached from the main dwelling. In the rear were the carriage house and the stalls for the horses.



New Orleans Vieux Carre

New Orleans is the city unique. It is old and it is new; it is ancient and it is modern. It is a city of pleasure and of business.

In the Vieux Carre, popularly known as the French Quarter, is to be found the atmosphere of old France and old Spain. Here is a typical Vieux Carre home, showing the patio.

Many of these patios are paved with stones and rocks brought as ballast to the city during its early days. The trees and plants are those found only in temperate climes.

Among the other distinguishing features of the Vieux Carre are the narrow streets, the peculiar architecture, the fan windows, the iron-trellised balconies, and the myriad-shaped roofs and chimneys. Landmarks of two centuries ago have been preserved in the Vieux Carre.

CERAMIC ABSTRACTS

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Ross C. Purdy, Editor

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The bold-face number following the journal name is the volume; the issue number is in brackets, followed by the page numbers, then the year in parentheses.

September, 1937

16—9

Abrasives

Care and preparation of polishing wheels. Robert T. Kent. *Metal Cleaning & Finishing*, **9** [6] 527–32 (1937).—The selection and procedure in the use of glue are all-important factors in the life of a polishing-wheel head. Glue should be strong, tough, flexible, and resistant to heat. Ground glue mixed with distilled water in proportions given for various abrasive grain sizes should be applied at a temperature between 150 and 160°F. Conditions that affect glue are enumerated. Details of preparation of the polishing wheel, application of the abrasive, drying of the wheels, balancing, and dressing are given. E.J.V.

BOOK

Abrasive Industry Calendar, 1937 (Schleifindustrie-Kalender). B. Kleinschmidt. O. Fischer and Söhne, Dortmund, Germany. 463 pp. Price 4 Rm. Reviewed in *Tonind.-Ztg.*, **61** [23] 275 (1937).—The following topics are discussed: (1) manufacture of abrasive disks, (2) bonds used, (3) hardness of abrasives, (4) testing of disks, and (5) selection and uses of abrasives. Tables with general and technical data are included. M.V.C.

PATENTS

Abrasive article. R. P. Courtney (Bakelite Corp.), Can. 366,651, June 8, 1937 (Nov. 23, 1935). R. H. Lombard and L. H. Milligan (Norton Co.), Can. 365,705, April 27, 1937 (July 25, 1936; in U. S., Nov. 23, 1935). E. S. Merriam. Can. 365,761, April 27, 1937 (May 2, 1936); see "Preformed—," *Ceram. Abs.*, **15** [10] 292 (1936). D. E. Webster (Norton Co.), Can. 365,539, April 20, 1937 (April 11, 1936); see *ibid.*, **16** [6] 165 (1937). G.M.H.

Abrasive article. H. C. Martin and F. A. Upper (Carborundum Co.). U. S. 2,084,534, June 22, 1937 (Sept. 28, 1933). The method of manufacturing resin-bonded abrasive articles comprises preparing a loose mass of abrasive grain to which is attached a fusible heat-hardenable resin solid at ordinary room temperatures and free from liquid plasticizers which mass because of lack of cohesion can not be molded at ordinary room temperatures, shaping an article by placing the mass in a mold and heating to an extent sufficient to make the resin adhesive and cause the article to retain its shape when cooled and removed from the mold but not enough to cure the resin, cooling the article in the mold until the resin hardens sufficiently to make the article self supporting, removing the article from the mold, and heating it to cure the resin.

Abrasive article. F. J. Tone (Carborundum Co.). U. S. 2,084,513, June 22, 1937 (Sept. 26, 1930; renewed Oct. 10, 1934). An abrasive wheel comprises a plurality of preformed shapes of bonded abrasive material and has cementitious joints between the abrasive shapes composed of a hard rubber binder together with a finely divided inert filler having a thermal expansion lower than that of the hard rubber.

Abrasive article. C. E. Wooddell and J. F. Barnes (Carborundum Co.). U. S. 2,085,137, June 29, 1937 (Dec. 8, 1933). A mix for making abrasive articles contains granular abrasive material, bond, and granulated coke.

Abrasive compound and means for utilizing. J. D. Kinsley. U. S. 2,084,644, June 22, 1937 (Dec. 4, 1931). An abrasive bite-rim composition comprises a mixture of gum damar, beeswax, gum tragacanth, French chalk, and abrasive material, the mixture being solid at tempera-

tures of 108°F and lower and becoming increasingly softer at temperatures above 108°F to a point of fluidity.

Abrasive stone holder. M. N. PRANGE. Can. 367,117, June 29, 1937 (Jan. 2, 1936). G.M.H.

Abrasive wheel. EDWARD VAN DER PYL (Norton Co.). Can. 365,540, April 20, 1937 (July 15, 1936); see *Ceram. Abs.*, **16** [4] 106 (1937). G.M.H.

Abrasive wheel and method of manufacture. BAALIS SANFORD AND D. E. WEBSTER (Norton Co.). U. S. 2,085,705, June 29, 1937 (Nov. 5, 1935). A method of making rubber-bonded abrasive bodies is described.

Arrangements for working the peripheral surfaces of grinding disks, etc. J. H. BODDEN. Brit. 466,261, June 9, 1937 (Dec. 18, 1935).

Automatic internal grinding machines. K. JUNG (trading as K. Jung Maschinenfabrik). Brit. 466,566, June 9, 1937 (March 28, 1935).

Automatically controlled abrading machine. R. A. COLE (Norton Co.). Can. 365,114, March 30, 1937 (Dec. 12, 1935). G.M.H.

Benches or work tables for drills, grinding machines, etc. L. SLEET. Brit. 467,646, June 30, 1937 (Dec. 23, 1935).

Buffing and polishing device. M. J. BAILEY. U. S. 2,085,140, June 29, 1937 (Jan. 3, 1936).

Buffing wheel. HARRY ZIMMERMAN. U. S. 2,087,012, July 13, 1937 (March 12, 1936).

Buffing wheel section. E. W. HALL. U. S. 2,087,105, July 13, 1937 (May 28, 1936).

Cam grinding machine. H. A. SILVEN (Norton Co.). Can. 364,644, March 9, 1937 (March 4, 1936). G.M.H.

Ceramically bonded abrasive article manufacture. F. L. NOBES (Carborundum Co.). Can. 365,054, March 30, 1937 (March 30, 1935). G.M.H.

Composite grinding wheel. BAALIS SANFORD (Norton Co.). Can. 365,702, April 27, 1937 (Feb. 3, 1936); see *Ceram. Abs.*, **16** [4] 106 (1937). G.M.H.

Crankpin grinding machine. H. A. SILVEN (Norton Co.). Can. 364,641, March 2, 1937 (Aug. 31, 1935). G.M.H.

Diamond embedded abrading tool. F. H. WILLEY. Can. 365,442, April 20, 1937 (June 10, 1935). G.M.H.

Grinding disk and method of making. H. H. BUDDS AND THOMAS GORZELANY (Briggs Mfg. Co.). U. S. 2,085,211, June 29, 1937 (Dec. 10, 1934).

Grinding machine. A. G. BELDEN AND F. E. DROWN (Norton Co.). Can. 365,703, April 27, 1937 (March 6, 1936). G.M.H.

Grinding machine. H. A. SILVEN (Norton Co.). U. S. 2,086,052, July 6, 1937 (June 26, 1936).

Grinding wheel. A. P. BEEBE (Peninsular Grinding Wheel Co.). U. S. 2,084,789, June 22, 1937 (June 13, 1936). A grinding wheel comprises a circular adapter having lateral and peripheral walls normal to each other, the walls being arranged inwardly of the outer periphery of the adapter, the adapter being provided with an annular groove in the peripheral wall, a plurality of clamps arranged adjacent the lateral and peripheral walls, a plurality of segments of abrasive material arranged between the clamps and the peripheral wall, means for moving the clamps toward the peripheral wall, and guiding means on each of the clamps extending into the annular groove.

Hone. H. L. BLOOD (Heald Machine Co.). U. S. 2,086,660, July 13, 1937 (Sept. 14, 1936).

Hydraulic cam grinding machine. A. G. BELDEN AND H. A. SILVEN (Norton Co.). Can. 364,642, March 2, 1937 (Jan. 27, 1936). G.M.H.

Hydraulic grinding machine. H. A. SILVEN (Norton Co.). Can. 365,704, April 27, 1937 (June 29, 1936); see *Ceram. Abs.*, **15** [11] 322 (1936). W. H. WOOD (Norton Co.). Can. 365,113, March 30, 1937 (March 30, 1935). G.M.H.

Hydraulic grinding wheel feeding mechanism. W. H. WOOD (Norton Co.). Can. 364,643, March 9, 1937 (Jan. 27, 1936). G.M.H.

Hydraulic surface grinding machine. J. R. WHITTLES (Norton Co.). Can. 365,115, March 30, 1937 (Jan. 30, 1936). G.M.H.

Hydraulically operated steady rest. C. G. FLYGARE (Norton Co.). U. S. 2,086,024, July 6, 1937 (Nov. 22, 1935).

Lapping machine. R. A. COLE (Norton Co.). U. S. 2,085,005, June 29, 1937 (July 6, 1936).

Machine for grinding locomotive wheels. V. L. MARTIN. U. S. 2,085,378, June 29, 1937 (April 8, 1936).

Machine for grinding and polishing the edges of glass, marble, or like plates. K. A. WEBER. Brit. 466,412, June 9, 1937 (Nov. 6, 1934).

Manufacture of abrasive-coated fabric. CARBORUNDUM CO. Brit. 467,111, June 23, 1937 (Dec. 11, 1934).

Manufacture of bonded abrasive articles. CARBORUNDUM CO. Brit. 467,434, June 30, 1937 (March 20, 1935).

Method and machine for grinding and polishing. N. H. KLAGES. Brit. 467,129, June 23, 1937 (Aug. 19, 1935).

Polishing wheel. K. H. BOWEN (Columbian Rope Co.). U. S. 2,085,142, June 29, 1937 (Aug. 31, 1936).

Roll grinding machine. C. G. FLYGARE AND H. B. FRIBERG (Norton Co.). Can. 364,961, March 23, 1937 (Dec. 30, 1935); see *Ceram. Abs.*, **16** [2] 55 (1937). G.M.H.

Roughening or sharpening of grindstones. W. VOITH, H. VOITH, AND H. VOITH (trading as J. M. Voith). Brit. 466,859, June 16, 1937 (Dec. 7, 1934).

Rubber-bonded abrasive article. D. E. WEBSTER (Norton Co.). Can. 364,646, March 9, 1937 (June 5, 1936). G.M.H.

Segmental grinding wheel. G. N. JEPPSON (Norton Co.). Can. 364,645, March 9, 1937 (May 29, 1936). G.M.H.

Surface grinding machines. K. JUNG (trading as K. Jung Maschinenfabrik). Brit. 466,370, June 9, 1937 (July 19, 1935).

Surfacing machine. G. M. CURTIN (Behr-Manning Corp. and Curtin, Hebert Co., Inc.). U. S. 2,086,516, July 6, 1937 (May 11, 1935).

Valve grinder. W. E. JESSOP. U. S. 2,084,959, June 22, 1937 (Nov. 17, 1934).

Valve-seat grinder. M. D. TYLER. U. S. 2,085,280, June 29, 1937 (Nov. 1, 1934).

Art and Archeology

American pottery industry. F. H. RHEAD. *Pottery & Glass Record*, **19** [6] 143 (1937).—The English and American pottery industries are compared with emphasis on the "silk screen" process of decoration. A.B.S.

Builders of Zimbabwe. J. F. SCHOFIELD. *Discovery*, **18**, 67–71 (March, 1937).—The puzzling African ruins of Zimbabwe are discussed in the light of the pottery found there. It is classified into three types, called R_1, R_2, and R_3. Illustrated. H.H.S.

Celadon. ANON. *China, Glass & Lamps*, **56** [9] 8 (1937).—Celadon is the French interpretation of the colors of some of the Chinese porcelains of the Sung dynasty. One color of the Lung-ch'uan porcelain was a green compared to fresh onion sprouts. The colors have become known as Celadons. Eventually the term was restricted to green, and the shade has become grayed and softened. G.M.P.

Ceramic discussions. RAOUL DE BLOTTEFIÈRE. *Céram., Verrerie, Email.*, **4** [2] 45–52 (1936).—Egypt was the cradle of European and of Asia Minor ceramics, and China was the source of ceramic knowledge for the rest of Asia. The most ancient Egyptian ceramic ware was mainly siliceous, up to 90 and 92% SiO_2. The most flourishing period of the Egyptian arts was the 17th Century B.C., and the ceramics of this period were a mean between porcelain and stoneware. The characteristic decorative symbols are the scarab, the symbol of creation and persistence of life; the lotus, representing the goddess of the north; and the papyrus, representing the goddess of the south. The formulas for the famous Egyptian blue are as follows: *frit:* quartz sand 40, chalk 33.4, black copper oxide 26.6%; *transparent flux:* quartz sand 30.8, pandermite (borocalcite) 33.8, Solvay soda 7.7, minium 27.7%; *opaque flux:* quartz sand 27.5, tin oxide 10.8, pandermite 30.2, Solvay soda 7.0, minium 24.5%. The most ancient Chinese pottery was of a very hard paste with a semi-opaque coat called "Celadon" of a gray-red or sea-green color. At this time appeared the "crackled" ware which was a voluntary exploitation of a technical defect, *i.e.*, filling the cracks in the coat caused by differences in expansion with a liquid coloring of metallic base. The base of true Chinese porcelain was kaolin and a feldspathic rock, flinty kaolin called petuntse. Metallic oxides were used for color ornamentation and flambé effects. Specialized Sinologists have classified Chinese porcelain according to the type of decoration and epochs: Chrysenthémo-poeonian (poeona-peony) family; Green family (T[illegible] period, 1368–1615); Rose family (Houng-tchi of [illegible]8–1506); Tsing family (1616–today); Tching-te (1506–1521). Japan and Korea were the first to feel the influence of antique Chinese ceramics. Persia was influenced both by China and India. Their pastes were composed mostly of a fusible siliceous element weakly agglomerated by a small amount of clay; firing was not continued until vitrification though some products became translucid. Asia Minor was subject to several influences, notably Persian in decoration. *Ibid.*, [4] 133–40; [6] 221–26.—The ceramic ware of the ancient Greeks did not have a dense structure and was consequently very porous; it was fired in an open fire and at low temperature. Its average chemical composition is silica 55, alumina 19, iron oxide 2.20, lime, magnesia 19, alkalis 3, undetermined and loss 1.80, which corresponds to the technical mix (fine clay 25 volumes, marl 30, and sand 45). At first, Greek pottery was entirely mat, and it was not until the time of Pericles that an alkaline silicate was used to coat the surface of vases, giving a black luster. The potteries of ancient Greece are differentiated according to their usage for drinking, storing, etc. Types are illustrated and described. The Etruscans produced interesting pieces both in form and decoration. The Romans had no new contribution to ceramics, but copied Greek methods and forms. The Italian influence on ceramic arts dates no further back than the 15th Century, the period of the Italian Renaissance. Roof and paving tile were used by the Arabs who also produced vases of elegant form and beautiful ornamentation composed of conventionalized flowers or interwoven floral motifs known as arabesques; no human or animal forms were used because of the prohibition of the Koran. The pottery of Majorca gave its name to majolica. In the Middle Ages pottery making was essentially a sedentary and local industry, each region having the personal characteristics resulting from the nature of the clays of the locality and the mentality of the natives. All methods were similar; these have been recorded in the archives of convents. Ceramic tiling and mosaics were also made. Artisans of all crafts were organized in the Middle Ages under strict regulations and all workmen were forced to belong if they wished to practice their trade. See *Ceram. Abs.*, **16** [8] 231 (1937). M.V.C.

Cultivation of crystals on glazes. J. W. MELLOR. *Trans. Ceram. Soc.*, **36** [1] 13–15 (1937).—Decorative crystalline effects can often be obtained from the formation of on-glaze crystals. Moisture condensed from the oven gases on cold ware absorbs the sulfurous gases and will dissolve unfired cobalt oxide. Upon evaporation of the solution, crystals are deposited and are fixed in the glaze by firing. Pleasing patterns are easier to reproduce than with in-glaze crystals since the process can easily be controlled. Crystal growth can be altered by the addition of traces of other substances. Illustrated with color plates. R.H.H.P., JR.

Faience of Nevers, 1645 to 1700. Classification attempted by origin of the ornamentation. C.-L. MEYER. *Céram., Verrerie, Email.*, **4** [2] 75–81 (1936).—Almost all the engravings, both French and foreign, which were copied trait for trait by the Nevers faience decorators, have been found and the names of the painters and editors with their probable dates have been ascertained from biographies and works of the artists. These data serve as a basis for calculating the probable date of execution of some of the famous pieces of faience of Nevers. The dates of several pieces produced between 1645 and 1700 are worked out by this system. M.V.C.

Japanese make pottery to compete with domestic ware. W. RICHARD BOYCE. *Ceram. Ind.*, **27** [2] 97–98 (1936).—As the hills near Seto are rich in suitable clays, many small plants there make ware for the Japanese market. The crudest methods are used, the workmen squatting on the floor before the Oriental adaptation of the potter's wheel. The ware undergoes the normal bisque and glost firing, but the decorating, most of which is done in Nagoya,

is unique. The design, usually a natural subject, is sketched on by master artists, and then the colors are filled in by less skilled workmen. The whole process of pottery production is seldom carried out in one factory; the clay is mixed in one factory, the ware is shaped and the bisque fired in a second, and glazing and decorating are done at other plants, so that one dish may be the product of four or five potteries. The decorating is often done at home by the workmen. The majority of the workmen are Korean or of Korean extraction, whose low standard of living makes them satisfied with the wage of about 15¢ for a 10-hr. day. E.J.V.

Palissy and Abaquesne. HELOT. *Céram., Verrerie, Email.*, **4** [1] 25–32 (1936).—Bernard Palissy has been considered the creator of French ceramics, but before his time an artist of Rouen, Abaquesne, was making true faience (1542), and beautiful objects of glazed clay by other artists had also appeared. Work by Abaquesne has been erroneously attributed to Palissy in spite of the Italian character of the work of Abaquesne and the distinctly French traits in that of Palissy. Abaquesne used a white enamel as background for motives of Italian origin carefully drawn in the manner of French Renaissance artists. The works of Palissy show the characteristics of material and make of the French enameled pottery of the latter Middle Ages and Renaissance which have no analogy with Italian faience with white background. Palissy was a potter, not a faience maker; he found a way of decorating clay with enamels of different color which had not been accomplished in France before. Palissy created a new decoration; his plates and vases are ornamented with shells, lizards, salamanders, frogs, snakes, eels, and fresh or salt-water fish. He was called the "inventor of rustic figulines" by his patron, Anne de Montmorency, who was the greatest collector of faience of the 16th Century. H. gives documentary evidence to support his contention. M.V.C.

Photography on porcelain. ANON. *Keram. Rundschau*, **44** [31] 365–66 (1936).—The implements and required chemicals are fully described. Minute details are given concerning the manufacture of the positive layer, copying, coating the photograph, and heating to middle red in a wood fire. F.E.V.

Pottery of the Middle Ages and Renaissance manufactured at Rouen. HELOT. *Céram., Verrerie, Email.*, **4** [6] 255–58 (1936).—The difference between glazed pottery and faience is not as marked as is believed; glazed pottery has a lead-containing coat and faience has a stanniferous coat. Potters formerly made a kind of faience without knowing it, as they were unaware of the presence of tin in their lead and did not know how to take advantage of exceptional results. The potters of the Middle Ages did not know about white enamel and decoration with colored enamels, but they knew how to disguise the disagreeable color of the clay under an opaque, nonstanniferous coat having some similarity with enamel. For decorating they used (1) a kind of engobe, (2) incrustation, (3) ornamentation in relief by attaching ornaments modeled separately, (4) casting, (5) slip applied with a brush, (6) sigillées (designs stamped in clay), and (7) two engobes superimposed. M.V.C.

Retrospection. J. W. MELLOR. *Trans. Ceram. Soc.*, **36** [1] 44–48 (1937).—M. discusses the liquation hypothesis of the white spotting of colored tile with reference to the earthworm marking on Chinese opaque glazes. The opalescence of the Chinese copper-red glazes is explained and illustrated by a color plate. Analyses of the Chinese glazes indicate that the proportion of alumina is low and that of lime high, a condition which favors the development of opalescence by the incipient devitrification of the glaze, and that phosphates are not needed as opacifying agents in these glazes. The behavior of phosphates in the bone-china body is described. Calcium phosphate produces a spongy glaze on overfiring n a reducing atmosphere by thermal decomposition. Ware containing ferrous phosphate will brown in such contact with aërial oxygen as is afforded by crazing cracks, even at ordinary temperatures. There is also evidence that partial oxidation of ferrous phosphate imparts a bluish tinge to the glaze. R.H.H.P., JR.

Roman roof tile. S. E. WINBOLT. *Discovery*, **18**, 86 (March, 1937).—Further examination of the tile factory excavated at Ewhurst, England (*Ceram. Abs.*, **16** [4] 108 (1937)) reveals roof tile of a type thought to be unique. The nearest known shape is the hexagonal stone slab. The tile are of red firing clay and are pear-shaped with nail holes in the top. Their dimensions are 1 in. thick, 15 in. long, 10 in. at the broadest part, and 3 in. at the top. Illustrated. H.H.S.

BOOK AND BULLETIN

Creative Art in England. WILLIAM JOHNSTONE. Stanley Nott, London, 1937. Price 21s. Reviewed in *Discovery*, **18**, 92 (March, 1937).—A corpus of English art from Anglo-Saxon times to the present is presented. H.H.S.

Use of Iowa clays in small-scale production of ceramic art. PAUL E. COX. *Iowa Eng. Expt. Sta. Bull.*, No. 133, 48 pp. (1937).—This bulletin was compiled to satisfy the requests from teachers, avocational workers, architects and artists, and commercial ceramic plants for strictly practical information on clay and glaze preparation, formulas, kiln plans, potters' wheel plans, and book and magazine lists. Iowa clays and shales and "mortar mix," which is finely ground shale sold in every Iowa lumber yard, are suggested as suitable raw materials. Sources of suitable sagger clays are named. Clay and glaze preparation methods are outlined in details covering the methods suitable for the small producer. A list of products which can be made in small plants is included. The technique of the potters' wheel is discussed. A method for making casting slips involving the use of the well-known Brongniart formula is presented. A convenient and inexpensive electric kiln of considerable capacity is shown in detail. The Norton-Duplin gas-fired kiln (*Jour. Amer. Ceram. Soc.*, **16** [3] 152–53 (1933)) is suggested as desirable for the avocational worker and teacher, and a modification simplifying the construction is also suggested. Rules are presented to permit scientific changes in glaze recipes by individuals not familiar with the usual technical methods. A comprehensive book and periodical list is included. While Iowa clays and shales are suggested as raw materials, clays and shales in any part of the country may be used. The bulletin is available without charge to all applicants. Illustrated by drawings and photographs. P.E.C.

PATENTS

Decalcomania paper. LEWIS DAVIS (McLaurin-Jones Co.). Can. 365,370, April 20, 1937 (April 17, 1935); in U. S., Aug. 23, 1934. JOHN MACLAURIN. Can. 364,720, March 16, 1937 (July 11, 1935); see *Ceram. Abs.*, **15** [7] 199 (1936). G.M.H.

Designs for:

Bottle. FRANK MCLAUGHLIN (Carr-Lowrey Glass Co.). U. S. 105,023, June 22, 1937 (Jan. 16, 1937). J. S. STEELMAN (Whitall Tatum Co.). U. S. 105,235, July 6, 1937 (May 21, 1937).

Candle holder. W. E. MACKELFRESH, JR. (Owens-Illinois Glass Co.). U. S. 105,118, June 29, 1937 (May 1, 1937).

Decanter. S. W. FISHER (Paden City Glass Mfg. Co.). U. S. 105,003, June 22, 1937 (April 28, 1937).

Defecator. W. C. GROENIGER. U. S. 105,006, June 22, 1937 (Jan. 5, 1937).

Floor tile. J. M. STRATTON (Gunderson Brick & Coal Co.). Can. 366,956, June 22, 1937 (June 29, 1936). Tile or brick of fired shale and sand, having uniformly distributed on its exposed surface a series of frustrums of equal height and size, which form, when such tile are assembled on a floor, drain channels. G.M.H.

Jar. B. D. FUERST (Owens-Illinois Glass Co.). U. S. 105,274, July 13, 1937 (Dec. 12, 1936).

Packer jar. F. J. PETTY (Ball Brothers Co.). U. S. 105,231, July 6, 1937 (Dec. 1, 1936).

Plate. YUKIO BUMA. U. S. 105,197, July 6, 1937 (May 26, 1937). SUSIE COOPER (Eugene L. Fondeville). U. S. 105,201 and 105,202, July 6, 1937 (May 1, 1937). DORIS JOHNSON (Mayer China Co.). U. S. 105,242, July 6, 1937 (May 25, 1937).

Spark plug. GUSTAV RUTHARDT. Can. 367,119, June 29, 1937 (Nov. 23, 1935). G.M.H.

Method of ornamenting glass. SEBET SILVERMAN. Can. 364,850, March 16, 1937 (Oct. 21, 1935). G.M.H.

Cements

Action of soda in solution on tetracalcic aluminum hydrate. JEANNE FORET. *Compt. Rend.*, **204** [18] 1335–37 (1937).—Soda was found to have an effect similar to that of lime; it favors the precipitation of calcium aluminates and decomposes the latter less than pure water. Beyond 0.04 parts of soda to aluminate, soda dissolves less Al. The analysis of the liquids showed that tetracalcic aluminates are decomposed under formation of soluble sodium aluminate and free insoluble lime. This decomposition is seen to be the cause of the disintegration of aluminous cements. M.H.

Agressivity and hydraulic additions. A. STEOPOE. *Zement*, **26** [11] 169–72 (1937).—Hydraulic additions, during binding, react with the liberated $Ca(OH)_2$ and form calcium hydrosilicates. These new bodies are unstable in the presence of aggressive solutions; they are already decomposed by pure water (hydrolysis) and evolve silica gel. The usual methods for determining free lime in clinker are not valid in the case of trass cement mortars on account of their physical structure and water content. Results found are too high. The favorable effect of trass additions in the presence of aggressive influences is due not to the binding of free lime but to the formation of calcium hydrosilicates which are quickly decomposed, giving silica gel. This gel is chemically resistant and waterproof. F.E.V.

Calculated and actual composition of Portland cement clinker. Cz. *Tonind.-Ztg.*, **61** [20] 236–37 (1937).—The use of Bogue's formula for calculating the mineralogical composition of Portland cement is discussed. The results are tabulated. M.V.C.

De-airing to increase the life of plaster molds. FRED C. HENDERSON. *Ceram. Ind.*, **27** [1] 32 (1936).—Using three mixes of plaster and water, tests were made on de-aired and nonde-aired samples. The de-aired mixes showed increases in modulus of rupture, dry density, and wet density, with a decrease in absorption. As de-airing should knit gypsum crystals more closely together and the increased density would indicate more of the crystals per unit volume, it seems reasonable that a longer life of the mold should follow. E.J.V.

Latest discoveries in cement. VIERI SEVIERI. *Tonind.-Ztg.*, **61** [17] 197–98 (1937).—References are given. M.V.C.

Microscopic study of cements. ERICH STACH. *Tonind.-Ztg.*, **61** [28] 318–19 (1937).—The use of a microscope for studying cements, as it is used in metallography, ore petrography, and especially in coal-powder petrography, is discussed. Details of procedure are given. Illustrated. M.V.C.

BULLETIN

Occurrence, properties, and preparation of limestone and chalk for whiting. HEWITT WILSON AND KENNETH G. SKINNER. *U. S. Bur. Mines Bull.*, No. 395, 160 pp. (1937). Price 30¢ from Supt. of Documents, Govt. Printing Office, Washington, D. C. The results of a study undertaken to encourage the use of domestic materials in the preparation of whiting are given. Chalk, limestone, and marble samples are described by states. R.A.HEINDL

Enamel

Career in enameling. EDWARD H. SYKES. *Ceram. Ind.*, **27** [2] 118–22 (1936).—S. traces the development of the Ingram-Richardson Mfg. Co. from the time of its foundation in 1901 to the present day, when it employs over 1000 people. The data presented are based on statements from both Ingram and Richardson. E.J.V.

Chemistry and mechanics of metal cleaning. D. J. BENOLIEL. *Ceram. Ind.*, **27** [1] 24–26; [2] 102–107 (1936).—Materials used for metal cleaning can be divided into those that clean (1) by solution, (2) by chemical action, (3) by emulsification, (4) by mechanical action, and (5) by combinations of the above. Solvents do not leave

metal surfaces clean enough for enameling. Cleansers of the second class act chemically and combine directly with saponifiable oils and greases, leaving the metals chemically clean and ready for enameling or a similar operation. The emulsifying cleansers combine physically with the materials to be removed owing to their "colloidal action," while cleansers of the fourth class depend upon mechanical agitation caused by something incorporated in them or by the way the cleanser is manipulated. The mechanical factors in cleaning metals for porcelain enameling and the testing of cleaning solutions are discussed in detail. E.J.V.

Continuous enameling furnace heated by radiant tube element. ANON. *Ind. Gas*, **15** [12] 9 (1937).—A counterflow continuous enameling furnace 85 x 15 ft. uses 3800 cu. ft. of natural gas per hour when firing 8000 gross lb. of ware per hour. A temperature of 1600°F is maintained in the firing section, and the spent gases are used in the preheating and drying chambers. See "Gas-fired—," *Ceram. Abs.*, **16** [6] 168 (1937). S.S.

Corrosion of various constructional steels: V. J. BRILLIE, A. LEROY, AND A. ROUX. *Welder*, **9** [41] 122–25 (1937).—Curves are given showing e.m.f. *vs.* time for the electrolytic potential cells set up using weld metal and parent metal as electrodes. Relationships are not entirely consistent, and the method of predicting corrosion behavior is considered inadequate. It is concluded that Cr and Cu, Mn and Si, and Ni additions improve chemical resistance. Ni is most effective in reducing seawater corrosion. Practical homogeneity exists across welded joints in regard to corrosion. W.H.B.

Deënameling, a rapid and economical method. J. NAPPÉE. *Céram., Verrerie, Email.*, **4** [4] 147–51 (1936); *Usine*, **45** [11] 29–30 (1936).—Deënameling by sanding is slow and suitable only for cast iron, as its thickness resists deformations due to the process. The use of acids for deenameling is detrimental to the metal. N. studied the use of the hot alkaline bath (caustic soda) for deënameling. The metal is not attacked and there are no noxious gases or vapors, although there is a bubbling and tiny droplets are projected, from which workmen must be protected. The installation to be used for deënameling in plants is described. M.V.C. + M.H.

Drawing and stamping compounds. CLYDE LOWE. *Enamelist*, **14** [9] 11 (1937).—Objections to the use of soaps, mineral-oil compounds, or compounds containing pigments or fillers for the drawing and forming of metal parts to be enameled are cited. L. recommends that a viscous compound of high-grade vegetable oils which is free from any pigment or filler, has no free fatty acid content, is freely soluble in water, and has an affinity for metal be used to assist in the drawing operation. E.J.V.

Elementary course in enameling. F. R. PORTER. *Ceram. Ind.*, **26** [4] 284–90; [5] 366–72; [6] 424–30; **27** [1] 46–52; [2] 124–30; [3] 210–16; [4] 286–90; [5] 368–74 (1936).—This very thorough course presents the pertinent steps in the entire process in a logical sequence. All matter of a technical nature is presented in as simple a manner as possible but no detail is omitted in explaining the intricacies of the processes involved in obtaining satisfactory porcelain enamel finishes. E.J.V.

Enamelers of the 19th and 20th centuries. GASTON RICHET. *Céram., Verrerie, Email.*, **4** [5] 177–82 (1936).—Etienne Tourrette (1858–1923) was a master technician and artist in the production of cloisonné, translucid enamels, plating, and enamel painting. He is especially renowned for his work in enamelware in "résille d'or." An example of this work which is in the Museum of Decorative Arts (France) is a gold vase entirely covered with enamel ornamented with leaves, flowers, fruits, and branches of translucid harmonious colors. The technique of production of this type of decoration and of the cloisonné enamelware of Tourrette is given. M.V.C.

Enameling mystery. ANON. *Metal Ind.* [London], **49** [24] 587 (1936).—The Schedula of Theophilus is among the interesting books on the subject of early metalwork. Theophilus referred to only one kind of enamel, and this he called electrum. Charles Thomas of Vittoria Street School for Jewellers, Birmingham, found that this method of enameling would not work on commercial gold (alloy of gold and copper) but gave very good results when used on an alloy of gold and silver, known in the old days by the name of electrum. Theophilus apparently called his enamel after the metal to which it could be applied. H.E.S.

Manufacture and properties of enameling iron. KARL KAUTZ. *Ceram. Ind.*, **27** [3] 179–81; [4] 261–62 (1936).—The basic open-hearth process is used to make practically all enameling iron. Sheets are made from ingots by either the slab (hot strip band) method or the bloom (sheet bar) breakdown method. Treatments given the sheet after it is rolled include normalizing, box annealing, pickling, cold rolling, and leveling. Defects which cause rejections of enameling sheets are enumerated. Properties of enameling sheets commonly checked on are grain structure, ductility, hardness, tensile strength, and enameling qualities. The grades of enameling sheets are pointed out, with the special properties and surface textures of each. E.J.V.

Mechanical drying in vitreous enameling. J. H. HOLLOWS. *Sheet Metal Ind.*, **11** [118] 211–14 (1937).—H. concludes that an efficient drier for general vitreous enamel work should embody as many as possible of the following points: (1) turbulent air conditions, (2) drying air of relatively high humidity, (3) at least two different sets of air conditions, (4) temperature inside the drier between 150° and 200°F, (5) indirect firing, if gas or oil is used, (6) as small a drier as possible, (7) tunnel type of machine wherever possible, (8) heating units located within the walls of the drier. With some work a number of these conditions are not possible of achievement, but as many as possible should be obtained, and turbulence is essential. A.P.S.

Porcelain enamel and the New York World's Fair. PAUL V. BLACKBURN. *Enamelist*, **14** [8] 14–17 (1937).—The Shelter Focal Center at the World's Fair of 1939 will have on its exterior a porcelain enameled mural 70 ft. long and 20 ft. high, with a wainscot 140 ft. long and 7 ft. high under it. The mural will be designed by J. Scott Williams and manufactured by the Ferro Enamel Corp., Cleveland. The mural will be made of 50 or more separate panels, each of which will be highly decorated; the work is to be done under studio conditions, with all firing being done in the furnaces of Porcelain Metals, Inc. E.J.V.

Porcelain enameling furnaces. F. S. MARKERT. Presented at Porcelain Enamel Institute Forum, Urbana, Ill., May, 1937; abstracted in *Enamelist*, **14** [8] 12–13 (1937). E.J.V.

Production of one cover-coat ware. HERMAN L. COOK. Presented at Porcelain Enamel Institute Forum, Urbana, Ill., May, 1937; abstracted in *Enamelist*, **14** [8] 10–11 (1937). E.J.V.

Proper firing of sheet-iron ground-coat enamel. H. C. BEASLEY. *Enamelist*, **14** [7] 9–12 (1937).—Proper firing of ground coat and cover coat involves the absorption of heat by the metal and enamel at a definite rate and in a definite quantity. In firing the ground coat it is necessary to absorb heat into the metal and enamel at a rate which will permit proper oxidation of the base metal without the enamel fusing to the extent that it seals the metal from further oxidation; the quantity of heat available must be sufficient to keep the enamel at its fusing point and quickly seal the metal from further oxidation after sufficient oxidation has been produced. The effect of furnace types and the materials used in the construction of the furnaces on the firing characteristics is discussed. Methods of controlling the various factors to eliminate possible defects in the enamel are described. E.J.V.

Radiographic examination of welds. V. E. PULLIN. *Welding Ind.* [London], **5** [3] 104–17 (1937).—Subjects covered are porosity, slag inclusions, cracks, lack of penetration, contrast, and definition as affected by scattering. The A.S.M.E. rule on acceptable porosity radiographs is criticized as intending to imply that the interpretation of the radiograph need not be made by an expert. The lack of a series of increasing thicknesses of section in the A.S.M.E. standards is considered a serious disadvantage for interpretation by other than an expert. Quantitative measurements of porosity are described as a remote possibility as a laboratory tool but impractical for industrial use; the drawback is the scattered radiation which precludes numerical results. Specific gravity figures from radiograph intensity values are also impossible since the intensity of the film depends not only on depth of flaw but also on its width, and scatter is different for exactly similar flaws occurring at different positions in the plate. Radiographs are shown which indicate porosity due to slag or gas and flaws due to cracking; these differences are detailed for the various films taken. Where there is marked slag porosity, the presence of cracks should be suspected; they are rarely associated with gas porosity. P. regards as a crack any flaw that is likely to spread; rounded ends would indicate nonspreading tendency. Lack of penetration is difficult to determine with radiograph, and distinction is made between patchy porosity and nonpenetration, although both are considered elements of danger in the weld. The quantitative measurement of size of flaw aimed for in the A.S.M.E. code, with a thickness greater than 2% of the thickness of the plate, is criticized as being dependent upon conditions of scattered radiation and related to focus of tube, thickness of the plate, and lateral size of the flaw. Many photos showing radiographs are impossible to interpret, apparently due to poor reproduction. In the discussion it is shown that two radiographs may be exactly similar as to porosity, but the density obtained in one case may be due to scattered areas of porosity, while in the other it may be due to concentrated porosity which would have entirely different effects on the properties of the weld. It is indicated that Lloyd's Register may drop the specific gravity requirement, since acceptable weld radiographs were found never to be less than 7.8. W.H.B.

Suitable structure of enameled kitchen ware. H. LANG. *Glashütte*, **67** [1] 5–8 (1937).—High-quality ground enamel should contain the normal amount of cobalt oxide and borax, the normal proportion of quartz and feldspar, and some manganous oxide to improve impact strength of the enamel. Additions of quartz, besides the usual mill additions of clay, soda, and borax, are to be avoided. Quartz added to the mill incompletely dissolves in the enamel on firing and is a source of various defects in the coat enamel. There are excellent acid-stable white-coat enamels, but they are not resistant to cooking. White opacifiers are not enamel formers and should be avoided if possible. Cerous oxide as opacifier is the best among them. The correct ratio of feldspar or kaolin to quartz should not be overstepped. Clay should be used only as a suspending agent. Antimony can be used only in the authorized form. The other opacifiers, such as fluorides and even tin oxide, lower the resistance to boiling. In general, however, white enamel should be replaced by colored enamels, as they possess a much greater resistance. The introduction of definite amounts of TiO_2 yields excellent results. M.V.C.

Trenkamps have made enameling history. WILSON B. FISKE. *Enamelist*, **14** [9] 18–19 (1937).—The Trenkamp family has operated a porcelain enameling plant for over 25 years in Cleveland, and its present organization, the Ohio Foundry Co., maintains an enameling division embodying latest efficiency methods. The company was among the first to enamel washing machines with production equipment, the one-coat tub, the all-white tub, and the washing machine tub on a fixture to support the bottom. All the ware is moved on a conveyer system built at the plant. E.J.V.

Water-wash spray booths in the porcelain enameling industry. ANON. *Enamelist*, **14** [9] 8–10 (1937).—A combination spray booth consisting of a dry reclaiming chamber and a wet dust-collecting compartment has been developed. Dry collection of approximately 85% of the spray dust takes place, and the undesirable spray dust, about 15%, is accumulated in the water-wash compartment, eliminating any objections of health authorities. Illustrated. E.J.V.

Welding malleable cast iron. Review of the literature to Dec. 1, 1936. W. SPRAGEN AND G. E. CLAUSSEN. *Welding Jour.* [N. Y.], **16** [6] Supp. 10–14 (1937).—The properties of welded black and white cast Fe are tabulated. 32 references. W.H.B.

World's largest continuous porcelain enameling furnace. ANON. *Enamelist*, **14** [8] 18–20 (1937).—A detailed description of the continuous porcelain enameling furnace in the plant of Norge Corp. at Muskegon Heights, Mich., which is capable of producing 5000 sq. ft. of ware per hour, is presented. Illustrated. E.J.V.

Zinc oxide. HARRY W. SMITH, JR. *Enamelist*, **14** [9] 12–13 (1937).—Zinc oxide gives improved color, gloss, and brilliance to glasses, glazes, and enamels and may add ma-

terially to surface hardness and durability. It also renders vitreous substances more elastic, in many cases increases acid resistance without impairing the opacity, and reduces frit solubility in mill liquor. In the "indirect" process, zinc oxide is produced through combustion of zinc vapor arising from boiling pots of molten metallic zinc. The more generally used "direct" process develops the end product directly from the ore by reducing the zinc ore with carbonaceous fuels and immediately burning the zinc vapor to zinc oxide in the same furnace. This material is a quality constituent in producing high-grade ceramic products. E.J.V.

PATENTS

Decorative coating and process of making. GEORGE SIROVY (Century Vitreous Enamel Co.). U. S. 2,085,875, July 6, 1937 (Oct. 2, 1936). The process of providing a decorating coating comprises applying a foundation coating, firing it, applying a liquid coating of base color, allowing the coating to partially dry so as to form an outer skin overlying a fluid layer of the base color, working the skin while it is floating on the fluid layer to cause it to wrinkle into a relief formation, thereafter spraying the relief formation from an angle with a contrasting color to effect an uneven application of the contrasting color on the base color, and finally firing the base and contrasting colors to provide a hard protective and decorative coating.

Enamel and glaze preparation. CARL OBERLÄNDER AND F. H. ZSCHACKE. Can. 365,909, May 4, 1937 (May 20, 1936). Method of producing a preparation for improving enamels and glazes comprises reacting compounds of magnesium, boron, silicic acid, and fluorine so as to produce a magnesium boro-fluorosilicate. G.M.H.

Enameling furnace. LEE WILSON AND J. C. WOODSON. U. S. 2,086,971, July 13, 1937 (Feb. 19, 1936).

Enameling machine. E. H. HARRIS (Wheeler Insulated Wire Co.). U. S. 2,087,145, July 13, 1937 (March 30, 1936).

Enamelware. J. E. ROSENBERG (O. Hommel Co.). U. S. 2,086,190, July 6, 1937 (June 3, 1935). In the method of coating an iron or steel article with enamel, the steps consist in providing upon the ferrous surface of the article a screen of inert material which affords localized and irregular protection against erosion, fusing upon the ferrous surface a coating of glass that contains an oxidizing agent in sufficient quantity actively to attack and erode the ferrous surface through the interstices of the screen, and allowing the so-coated article to grow cold, whereby the ferrous surface is pitted, the molten glass is caused to penetrate the pits, and the solidified coating is keyed to the metal.

Enamelware method. J. E. ROSENBERG (O. Hommel Co.). Can. 366,957, June 22, 1937 (Dec. 31, 1935; in U. S., Jan. 10, 1935); see preceding patent. G.M.H.

Manufacture of washtubs. F. M. VOGAN (Reeves Mfg. Co.). U. S. 2,084,467, June 22, 1937 (Nov. 23, 1934).

Means for applying vitreous enamel. G. L. STRUBLER (Corning Glass Works). U. S. 2,085,278, June 29, 1937 (Feb. 9, 1933).

White clouded enamel. IGNATZ KREIDL. Can. 366,392, May 25, 1937 (Aug. 20, 1936). G.M.H.

Glass

Accelerating glassmelting. M. G. CHERNYAK. *Keram. & Steklo*, **13** [3] 23–25 (1937).—The effect of the grain size of the batch on the rate of melting is discussed in detail. A dust-like batch is recommended for melting. M.V.C.

Change from oil to gas improves glass feeders. ANON. *Ind. Gas*, **15** [12] 10 (1937).—Three melting furnaces of 35, 50, and 100 tons capacity supply 16 bottle machines. Each feeder is 80 in. long and 26 in. wide outside, and is equipped with six low-pressure inspirator gas burners. A gas-fired furnace is used to preheat the plugs and tubes used in the feeders. S.S.

Compressibility of fused-quartz glass at atmospheric pressure. WALTER B. EMERSON. *Jour. Research Nat. Bur. Standards*, **18** [6] 683–706 (1937).—The compressibility of fused-quartz glass was determined with sufficient accuracy to establish the required corrections for change of length with change of pressure of the fused-quartz étalons used in a Fabry-Perot interferometer to evaluate the indices of refraction of air for converting standards of wave-length in air to their value *in vacuo*. Compressibility determinations were made for the same changes of pressure that were used for index measurements, *viz.*, from vacuum to atmospheric pressures. Determination of the compressibility of fused-quartz glass was made by interferometric comparison of the relative change in length of end gages of fused quartz and stainless steel. Values for the compressibility of both fused quartz and stainless steel were also determined by a direct method which depended upon the relative change in length of a closed tube and a solid gage of the same material. By this method the compressibilities were determined independently. Relative values for fused quartz and stainless steel were also derived from comparative changes in length with pressure of tubes and gages of dissimilar materials. The measurement for the longitudinal compressibility of clear, annealed, fused-quartz glass for a pressure of 1 atm. was 9.9×10^{-7} and for heat-treated, 14% chromium steel for a pressure of 1 atm., 3.1×10^{-7}. R.A.H.

Contact glasses. GORDON M. BRUCE. *Amer. Jour. Ophthalmology*, **20** [6] 605–18 (1937).—The application of ground and blown contact lenses to the correction of eye defects is fully discussed. See "Invisible—," *Ceram. Abs.*, **16** [1] 13 (1937). A.P.

Crystallization of ordinary sodium silicate glass. HARTMUT WIEHR. *Sprechsaal*, **70** [11] 146–49; [12] 158–61; [13] 173–74; [14] 182–84; [15] 198–201 (1937).—The purpose of this study was to determine the dependence of crystallization on temperature and time and the effect of the nature of surfaces, air moisture, and of the surrounding medium on crystallization. Experiments at lower temperatures were conducted to determine whether crystallization of glass near or below the transformation point is possible. To eliminate difficulties which may appear because of the change in concentration ratios and through the diffusion of glass components during crystallization of complex glasses whose crystallization products have a different chemical composition than the glass itself,

glasses with almost stoichiometric composition were selected, *e.g.*, sodium metasilicate and sodium disilicate glasses in which only a one-phase devitrification was observed. The crystallization of glasses was determined by means of a microscope, ultra-microscope, X-ray, and phosphorescence. The last method is made possible by the fact that glass exposed to X-ray fluoresces only, while crystallized samples phosphoresce also. The results of the detection of crystallization by different methods agree well. In vitrified sodium silicate the crystallization temperature (398 ± 4°C), which lies a few degrees above the transformation point (390 ± 5°C), was determined. No devitrification was observed below the transformation point. The curve of crystallization velocity of sodium disilicate glass is similar to curves of complex technical glasses. The results of the determination of the effect of surface nature on crystallization for sodium disilicate show that the number of crystals per surface unit increases according to different surfaces in the following sequence: fire-polished surface, "reflecting" surface of "fracture," ground-polished surface, fine-polished surface, and coarsely polished surface. The crystals have practically the same size in the different surfaces, except the fire-polished surface, with constant conditions of crystallization. Only crystals of medium size were observed on each surface. It is concluded, therefore, that all crystal nuclei were formed approximately at the same time. This was confirmed by further experiments in which crystals were grown after interrupting annealing and chilling the glass samples to room temperature, as no new crystallization centers were formed. The crystallization experiments on vitrified sodium disilicate in a vacuum, in nitrogen, and in air showed that the number and size of crystals were smaller on the surface annealed in a vacuum than on that annealed in air. Experiments made in dried air and in dried nitrogen showed a different number and size of crystals on the surfaces than on those treated in moist air. Annealing glass in a vacuum below the transformation point greatly increased the number of crystals, which were formed at higher temperature and in dried air. It is assumed that the processes of crystallization of glasses are similar to those of the recrystallization of crystals. On the basis of temperature laws for the formation of granules and their growth at recrystallization, it is assumed that the crystallization of glass below the temperature of transformation and a further growth of crystals already present are quite possible, although these temperature laws for devitrification are unknown. From experiments with surface crystallization, W. concludes that crystal nuclei are formed on predetermined places of the surface during devitrification and that their energy is influenced by the adsorption of molecules of the surrounding gases or steam. Whether a definite time is necessary for the formation of crystal nuclei during devitrification could not be determined. The rate of crystallization on the surface depends slightly on the structure or nature of the surface, but it is influenced by gas. M.V.C.

Furnace for studying fusion and degasification in glass manufacture. Bromlei. *Tekhnika* [U. S. S. R.], No. 21, p. 410 (1935).—The furnace installation in the Research Institute of Glass in Moscow is the only one in the world. In this furnace it is possible to effect electrofusion of glass in complete vacuum or under a pressure of 150 atm. During the investigation it is possible to check and to take photographs of the process of fusion, to operate the crucible exteriorly, and to obtain high temperatures, about 1500°C, at high pressures. The electrofusion in vacuum represents a complete reorganization in glass manufacture and shows the possibility of the mechanization and automatization of glass production. B.E.K.

Gases in some optical and other glasses. Clarence Hahner, George Q. Voigt, and Alfred N. Finn. *Jour. Research Nat. Bur. Standards*, **19** [1] 95–103 (1937); R.P.1014. Price 5¢.—An apparatus and method for removing the gases dissolved in glass by vacuum fusion and for determining the quantity of gases are described. Determinations of gases in 3 types of optical glass and 7 commercial glasses were made. Approximately the same quantities of water were found in both glasses, but the total volume of other gases, such as CO_2, SO_2, O_2, etc., never exceeded 10 ml./100 g. of optical glass, while the window glass contained from 34 to 73 ml./100 g. of glass. In the optical glasses, especially the light barium crown glass, there was no indication of a relation between the quantity of gas obtained and the number of "seeds" in the glass or any significant change in the gas content of the glass during the stirring and fining periods. R.A.H.

Heat transfer in glass tanks. C. Cone. *Ceram. Ind.*, **27** [1] 34–42 (1936).—The hypothesis is that secondary phases of heat flow through the molten glass bath and tank blocks have an important effect in determining melting capacity and glass quality. If empirical data are valid and assumptions correct, the following conclusions may be drawn: (1) Most commercial glasses are relatively transparent to black-body radiation at tank combustion temperatures; the effect of such radiation will be detectable at depths up to 12 in. (2) A relatively shallow primary convection circulation exists in melting tanks; this isolates the top layer of glass. Movement of glass through the tank is essentially confined to this primary layer. (3) The capacity of a given tank for producing seed-free glass is a function of the depth of the primary layer. (4) The depth of the primary layer depends on temperature gradients in the molten glass and can be varied by influences changing the shape of isothermal lines. (5) Luminous carbon radiation in the flame, since it is absorbed below the glass surface, lowers the critical isothermal boundary as compared to equal heat transfer by conduction, and thus tends to increase tank capacity, improve fuel economy, and reduce refractory maintenance when properly controlled. E.J.V.

Making Coca-Cola bottles. J. B. Nealey. *Ceram. Ind.*, **27** [2] 114–16 (1936).—N. gives a detailed description of the plant and operations of the Chattanooga (Tenn.) Glass Co., which uses gas in melting, glazing, and annealing operations while turning out 30,000,000 bottles a year. E.J.V.

Making glass for Ford V-8's. Anon. *Ceram. Ind.*, **27** [3] 170–78 (1936).—In the three million dollar plate-glass plant at Ford's Rouge Works in Dearborn, Mich., modern processing advances are found in (1) the completely automatic and dustless method employed in batch handling and weighing, (2) briqueting of the mixed batch, (3) a unique manner of handling the glass during grinding and polishing, (4) reclaiming of water used in grinding and

polishing, (5) labor and time-saving machines used for cutting windows and windshields, and (6) many control devices on the production line. A complete description of the methods used is presented. Illustrated. E.J.V.

Mending molds in the glass industry. ANON. *Nickel Bull.*, **10** [5] 120 (1937).—Cast-iron molds used in the glass industry often become defective through the development of pits or cracks which cause flaws in the finished product. If these irregularities are drilled out, they may be plugged with soft Monel wire, and, after smoothing off, the mold is again ready for use. Repeated tests showed that Monel plugs will not loosen, corrode, or mark the glass. H.H.S.

Metallurgical needs of the glass industry. R. D. SMITH. *Glass*, **14** [3] 88 (1937).—Metals consumed in the manufacture and handling of glassware are divided into (1) equipment subject to wear and abrasion in the handling and mixing of the raw materials, oxidation and wear of the furnace parts, and grinding and finishing operations on the glassware; and (2) parts for handling and shaping the molten glass. The requirements of the metal to be used in the major pieces of equipment are suggested. M.C.S.

Press molds from special steel. M. A. LIPSHITZ. *Keram. & Steklo*, **13** [4] 29–32 (1937).—The use of steel press molds for special glassware is discussed. Experiments showed that (1) the steel must be entirely uniform; (2) the polished surfaces can not oxidize under the conditions at which glassware is pressed (950 to 1050°C) and under the effect of molten glass; (3) the coefficient of linear expansion of the steel must be as low as possible; (4) steel must be easily worked; (5) the surface should be easily polished; and (6) the steel should not crack because of sudden temperature variations. The composition of these special steel alloys is discussed. M.V.C.

Seeds in soda-lime glass. A. E. BADGER. *Ceram. Ind.*, **27** [1] 17–21 (1936).—In an attempt to summarize information on seeds, B. discusses the amount of gas liberated by a batch on melting, effect of minor changes in composition, presence of dissolved gases in glass, effect of temperature, pressure, and stirring on the gases in glass, use of fining agents, influence of furnace atmosphere, and refractories as causes of seeds. Z. C. KLINE. *Ibid.*, [3] 208.—When a change to natural gas fuel resulted in seedy glass, the seeds were eliminated by changing the burners so the gas could enter the furnace at a lower velocity and the flame was more luminous and had a softer rolling effect. It was also possible to lower the melting-end temperature about 30° with no harmful results. E.J.V.

Shatterproof glass produced in Germany. ANON. *Chem. & Met. Eng.*, **44** [3] 167 (1937).—Plexiglass, a polymerized methyl ester, is strictly an organic glass without a silicate foundation and is not attacked by air, rain, or acids; certain organic chemicals, however, such as benzol, chloroform, and alcohol, dissolve it. This glass has been found suitable for use in airplanes and automobiles, having high strength and weighing less than half as much as silicate glasses. See "Multilayer—," *Ceram. Abs.*, **16** [5] 147 (1937). M.C.S.

Spun glass and kieselguhr as heat insulation. H. WALLS. *Brennstoff- & Wärmewirt.*, **19** [1] 1–6 (1937).—The general insulating properties of spun glass and kieselguhr are compared; from the standpoints of technical suitability and economy, both are considered satisfactory. For any installation strict account must be taken of the thermal conductivity at the actual operating temperature; hence handbook and laboratory values must be used with extreme caution. F.P.P.

Status of glass decoration in Germany with examples. W. VON EIFF. *Glastech. Ber.*, **15** [1] 25–36 (1937).—A cross-section is given of the status of glass decoration in Germany, including hollow ware, tableware, glass painting, and glass mosaic. E. first gives a short review of the development of glassworking in general from technical and style viewpoints to facilitate a more intelligent evaluation of recent works and endeavors. Illustrated. G.R.S.

Surface cracks in glasses. E. N. DA C. ANDRADE AND L. C. TSIEN. *Proc. Roy. Soc.* [London], **A159**, 346–55 (1937).—By attack with sodium vapor at about 350°C, a series of fine lines are developed on the surfaces of hard glasses which, by their nature, position, and direction, can not be attributed to mechanical scratches. These lines are not found with freshly drawn specimens but are frequent on the same glasses after several hours aging. The authors believe that they are visual evidence of the existence of the minute surface flaws postulated by A. A. Griffiths as responsible for the breaking of glass below its theoretical strength. On annealed optical glass they form an orthogonal system which may arise in directions normal to the principal stresses. Other surface markings, such as scratches and drawing marks, can be developed by hydrofluoric acid attack; the "Griffiths cracks" can not be so brought to light. Etching by hot sodium vapor may be a valuable method of investigating the structure of glasses. Sixteen photographs of etch figures are included. A.P.

Thermal expansions of some commercial glasses. A. E. BADGER AND R. C. TAYLOR. *Ceram. Ind.*, **26** [6] 416–17 (1936).—Data are presented on the chemical composition, thermal expansion coefficients, softening temperatures, and thermal expansion curves of thirteen commercial glasses. E.J.V.

BULLETIN

Nepheline syenite rock as a partial substitute for soda ash in the glass industry of India. V. S. DUBEY AND P. N. AGARWALA. *Bull. Ind. Research Bur., Govt. of India*, No. 7, 19 pp. (1937). Price 8d. Most of the glass made in India is soda-lime glass, for which the raw materials required are sand, lime, and soda ash. The first two are abundant in India, but soda ash has to be imported at a price about 50% higher than it is in England and other countries which produce their own. On the average, soda ash represents a considerable proportion (about 75%) of the cost of raw materials for making glass in India. The authors' experiments show that it is possible to replace about 50% of the soda ash used by Indian glass manufacturers with alkali-containing rocks and minerals occurring in India, provided that the percentage of alumina introduced into the glass does not exceed about 8%. It is claimed that this will reduce the cost of raw materials by 30%. More than one kind of rock could be used for this purpose, but the authors conclude that nepheline syenite rock is superior to other alkali-containing rocks, such as graphitic granite and feldspar, as a glassmaking material, as it is easily accessible, occurs in large deposits, and con-

tains about 15% alkali, mostly Na_2O. Nepheline syenite rock batches can be easily worked in the present direct-fired pot furnaces. With two different glasses having the same chemical composition but deriving their alkali from nepheline syenite and feldspar, the one containing nepheline rock melts much more easily than the glass containing feldspar. The only drawback to this glass is that it is highly colored. The percentage of iron introduced into glass by the use of nepheline syenite rock is too high to be neutralized by using manganese dioxide as a decolorizer; hence it is not possible to obtain perfectly colorless glass by the use of this rock in its natural form. The ferro-magnesium minerals, however, could be easily and cheaply extracted from the rock by electromagnetic separators. The occurrence in India and chemical composition of alkali-containing rocks and minerals, particularly nepheline syenite rocks, are described. It is pointed out that good glass varying in color from deep green to strong amber can be prepared from nepheline syenite batches simply by the proper adjustment of the percentage of manganese dioxide in the batch. A.P.SOM

PATENTS

Apparatus for drawing sheet glass. PILKINGTON BROS., LTD., AND J. B. WATT. Brit. 467,580, June 30, 1937 (Dec. 18, 1935).

Building block. J. C. KEANEY (Sam B. Meyer). U. S. 2,086,185, July 6, 1937 (Aug. 24, 1936). A masonry block comprises an integrally blown hollow glass building block or brick having stress-resisting walls, one of the walls including an opening remaining after the removal of a blow neck, as described, and an independently formed shield assembled with the wall and over the opening.

Ceramic stack. H. C. BATES (Corning Glass Works). Can. 364,913, March 23, 1937 (Oct. 18, 1934). G.M.H.

Device for the stopping of melted glass at the outlet of a tank furnace, and installations provided with the device. COMPAGNIES RÉUNIES DES GLACES ET VERRES SPÉCIAUX DU NORD DE LA FRANCE. Brit. 466,437, June 9, 1937 (March 28, 1935).

Double-wall glass container producing machine. JOKOB DICHTER. Can. 366,368, May 25, 1937 (Jan. 29, 1936). G.M.H.

Drawing glass. W. J. WOODS (Corning Glass Works). U. S. 2,085,245, June 29, 1937 (Oct. 22, 1930).

Forehearth for molten glass. K. E. PEILER (Hartford-Empire Co.). U. S. 2,085,328, June 29, 1937 (Dec. 14, 1935).

Forming machine for glass bottles, jars, etc. T. F PEARSON. Brit. 466,575, June 9, 1937 (Nov. 30, 1935).

Forming machine for glassware. T. F. PEARSON. Brit. 467,350, June 30, 1937 (Jan. 22, 1936).

Glass article forming machine. JOKOB DICHTER. Can. 366,370, May 25, 1937 (Jan. 29, 1936). G.M.H.

Glass article tempering method. J. T. LITTLETON (Corning Glass Works). Can. 366,949, June 22, 1937 (Feb. 8, 1935; in U. S., April 17, 1935). G.M.H.

Glass batch and process of making. H. P. EELLS, JR., AND H. N. BARRETT (Non-Metallic Minerals, Inc.). U. S. 2,084,328, June 22, 1937 (March 4, 1935). A glass furnace charge comprises silica, soda, and a lime component, part at least of the lime component embodying the reaction product of a limestone calcined with an aluminous flux.

Glass beveling machine. R. B. SMITH. Can. 365,006, March 23, 1937 (Aug. 21, 1935). G.M.H.

Glass closure for metal containers. R. D. SMITH (Corning Glass Works). U. S. 2,085,277, June 29, 1937 (Feb. 11, 1935; Nov. 21, 1935).

Glass gathering apparatus. A. C. PARKER (Libbey Glass Co.). Can. 365,697, April 27, 1937 (Jan. 27, 1936). H. R. SCHUTZ (Libbey Glass Co.). Can. 365,698, April 27, 1937 (Jan. 27, 1936). G.M.H.

Glassmaking apparatus. VERGIL MULHOLLAND (Hartford-Empire Co.). Can. 364,432, March 2, 1937 (May 2, 1935). G.M.H.

Glass mold. JOKOB DICHTER. Can. 366,369, May 25, 1937 (Jan. 29, 1936). G.M.H.

Glass mold. C. J. DOCKRAY AND H. J. DOCKRAY. U. S. 2,084,794, June 22, 1937 (Jan. 2, 1935; July 10, 1935).

Glass panel building construction. R. L. HOHL. Can. 365,274, April 6, 1937 (Nov. 4, 1935). G.M.H.

Glass plate edge grinding machine. N. H. KLAGES. Can. 366,565, June 1, 1937 (May 26, 1936); see "Edge —," *Ceram. Abs.*, **16** [7] 204 (1937). G.M.H.

Glass tempering process. LAMBERT VON REIS (Vereinigte Glaswerke Aachen, Zweigniederlassung der A.-G. der Spiegelmanufakturen und Chemischen Fabriken von St. Gobain, Chauny & Cirey). Can. 364,969, March 23, 1937 (March 13, 1936). G.M.H.

Glass toughening method. FRITZ ECKERT. Can. 367,024, June 29, 1937 (April 26, 1934). G.M.H.

Glass vessel manufacture. JOKOB DICHTER. Can. 366,367, May 25, 1937 (Jan. 29, 1936). G.M.H.

Glassware forming machine. FRANK O'NEILL. Can. 366,247, May 18, 1937 (Sept. 26, 1935). G.M.H.

Glass wool manufacture. G. SLAYTER AND J. H. THOMAS, JR. (Owens-Illinois Glass Co.). Can. 367,047, June 29, 1937 (Feb. 15, 1935). G.M.H.

Hollow glass article forming machine. W. H. WATKINS AND C. C. KINKER (Owens-Illinois Glass Co.). Can. 366,680, June 8, 1937 (Jan. 2, 1936). G.M.H.

Hollow glassware production. G. E. ROWE (Hartford-Empire Co.). Can. 366,669, June 8, 1937 (May 11, 1936); see "Method of making glassware," *Ceram. Abs.*, **16** [2] 62 (1937). G.M.H.

Laminated glass manufacture. R. H. DUBOIS (American Window Glass Co.). Can. 366,651, June 8, 1937 (May 19, 1936). G.M.H.

Large glass article casting apparatus. G. V. MCCAULEY (Amory Houghton). Can. 366,948, June 22, 1937 (Dec. 23, 1935). G.M.H.

Machine for forming hollow glassware. T. F. PEARSON. Brit. 467,452, June 30, 1937 (Jan. 22, 1936).

Manufacture of glass. T. F. PEARSON. Brit. 466,797, June 16, 1937 (Dec. 5, 1935).

Manufacture of safety glass. OTTO HAUPPE (Deutsche Celluloid-Fabrik). U. S. 2,087,090, July 13, 1937 (May 8, 1935).

Manufacture of splinterless glass. I. G. FARBENINDUSTRIE A.-G. Brit. 467,428, June 30, 1937 (Dec. 14, 1934).

Method of making glasses resistant to alkali-metal

vapors. R. H. DALTON (Corning Glass Works). U. S. 2,085,251, June 29, 1937 (Nov. 6, 1934). The method of treating glass to make it resistant to discoloration by hot alkali-metal vapors includes wetting the surface of the glass with a solution consisting of an alkali compound and a solvent, and heating the glass to fuse the alkali compound to the glass in a homogeneously attached, substantially transparent layer which is thick enough to prevent discoloration of the glass by the alkali-metal vapor and thin enough to resist cracking and crazing.

Mineral wool. H. T. Coss (Johns-Manville Corp.). Can. 365,644, April 27, 1937 (May 17, 1935). G.M.H.

Mineral wool mixture. J. B. NEAL (Johns-Manville Corp.). Can. 365,645, April 27, 1937 (July 5, 1935). G.M.H.

Opaque lead glass of low melting point. J. E. ROSENBERG (O. Hommel Co.). U. S. 2,084,747, June 22, 1937 (Aug. 17, 1934). A low melting-point lead glass smelted from a batch of which lead oxide is by weight the major component and whose melting point does not exceed 1400°F, in which there is additionally present an opacifying content of lead phosphate.

Protective glass containing neodymium. DEGEA AKT.-GES. (Auerges.). Brit. 466,262, June 9, 1937 (May 25, 1936).

Refractory glasses. GENERAL ELECTRIC CO., LTD. (Patent-Treuhand-Ges. für Elektrische Glühlampen). Brit. 467,362, June 30, 1937 (April 6, 1936).

Shaped glass article. A. H. STEWART. Can. 366,750, June 8, 1937 (June 17, 1936). G.M.H.

Shaped glass article and method of producing. A. H. STEWART. Brit. 467,221, June 23, 1937 (June 23, 1936).

Silica sand purification method. F. W. ADAMS (Frederick William Adams and Rockware Glass Syndicate, Ltd.). Can. 366,151, May 18, 1937 (Sept. 5, 1934). G.M.H.

Splinterless materials, particularly splinterless glass. GEORG KRÄNZLEIN (I. G. Farbenindustrie A.-G.). U. S. 2,086,506, July 6, 1937 (April 16, 1931). (1) A splinterless glass consists of two sheets of glass having interposed therebetween as a binding agent to secure adhesion of the glass sheets a product of the conjoint polymerization of vinyl acetate and acrylic acid ester. (2) A laminated object comprises at least one sheet of glass and a film comprising a polymer of a mixture of at least two unsaturated organic compounds.

Tempered glass and process for manufacturing. SOC. ANON. DES MANUFACTURES DES GLACES & PRODUITS CHIMIQUES DE ST.-GOBAIN, CHAUNY & CIREY. Brit. 467,607, June 30, 1937 (Dec. 22, 1934).

Structural Clay Products

Colors for sand-mold brick. F. E. LOBAUGH. *Bull. Amer. Ceram. Soc.*, **16** [7] 279–82 (1937).

Standard testing method in heavy ceramics. H. HECHT. *Tonind.-Ztg.*, **61** [24–25] 277–82 (1937).—H. discusses testing methods used for determining some properties of brick, such as strength and density, and the effect of moisture and weathering on them. Standard testing methods used in Germany and other countries and some experiments made in the laboratory of the Tonindustrie are described. The results are given in tables. A literature index is given. M.V.C.

Stoneware pipes for house connections. E. S. STOKES. *Clay Prod. Jour. Australia*, **4** [7] 15–17 (1937).—The fact that the lines are buried and situated so as to make adequate inspection difficult makes the use of cement impractical. Improvements in the manufacture of cement pipe do not diminish their liability to attack. Stoneware is resistant to the destructive agencies and should always be used for sewers and drains. H.H.S.

Strength of brickwork in relation to that of brick and mortar. N. DAVEY. *Brit. Clayworker*, **46** [542] 87 (1937).—The results of tests on small piers are as follows: (1) no increase in strength is to be gained by using, with the particular type of brick used in this study, a mortar richer than 1 (cementitious):3 (sand) by volume; in fact, a decrease is to be expected; (2) lime up to 50 to 60% of the volume of the total cementitious material, *i.e.*, lime plus cement, can be used in a 1:3 mix without any appreciable fall in pier strength; and (3) there is little increase in pier strength when mortar having a crushing strength higher than 1000 lb./in.^{2} is used. A rounded sand was used in the mortar. R.A.H.

Transverse and compressive strength of building brick. J. W. MCBURNEY. *Brit. Clayworker*, **46** [542] 88 (1937).—M. summarizes current methods of testing the transverse and compressive strength of building brick and the effect of certain variables, *e.g.*, method of capping specimens, on the results. R.A.H.

Wick test for efflorescence of building brick. JOHN W. MCBURNEY AND DOUGLAS E. PARSONS. *Jour. Research Nat. Bur. Standards*, **19** [1] 105–109 (1937); R.P. 1015. Price 5¢.—The wick test used at the National Bureau of Standards for indicating the tendency of brick to be a source of efflorescence on masonry is described, and the scale of grading used in reporting and comparing the results is outlined. Comparisons are made between the performance of brick in the test and the appearance of efflorescence on brick masonry exposed to the weather at Washington, D. C. The results showed that (1) if considerable efflorescence appeared on brick in the 5-day wick test, masonry panels built of brick of the same brand showed an objectionable amount of efflorescence; (2) if the efflorescence on brick in the wick test was only a trace or less, most of the masonry panels built from the same brand of brick showed only a slight amount of (or no) efflorescence; and (3) soluble salts from mortar appeared to have caused efflorescence on some of the panels. R.A.H.

PATENTS

Building brick. T. O. RAAD. U. S. 2,086,989, July 13, 1937 (Nov. 11, 1936).

Hollow brick closing apparatus. A. H. ULLRICH. Can. 365,306, April 13, 1937 (July 22, 1935). G.M.H.

Manufacture of brick, blocks, etc. A. VAN DER OORD. Brit. 466,920, June 23, 1937 (April 21, 1936).

Waterproof wall. E. J. WALSH. U. S. 2,085,618, June 29, 1937 (July 29, 1935). In a wall structure, inner and outer layers of a brick and a waterproof multiple sheet member interposed between the inner and outer layers of brick.

Refractories

Action of slags on refractories and some methods of testing. A. E. Dodd. *Trans. Ceram. Soc.*, **36** [2] 63–73 (1937).—Factors in the action of slag as a cause of refractory failure are treated with a view that in practice only the properties of the refractory can be altered. D. discusses the resistance of the various refractory compositions such as silica, magnesite, fire clay, and chrome-magnesite, together with examples of the use of equilibrium diagrams in predicting the extent of slag attack. The importance of the physical properties, texture, tensile strength, resistance to abrasion, thermal conductivity, and emmissivity, is indicated. The chief difficulties encountered in laboratory slag tests are the complete reproduction in the laboratory of working conditions or, conversely, the elimination of all but one factor and the quantitative measurement of the results obtained. Future research should be conducted on those chemical and physical effects which are fundamental. R.H.H.P., Jr.

Analysis of design and construction of hot-blast stoves. Albert Mohr, Jr., and Fred Wille. *Iron Age*, **136** [1] 12–17 (1935).—In design of a hot-blast stove the prime consideration is structural stability. This depends on (1) thickness of the brick, (2) size and shape of the brick, (3) arrangement of brick and fillers to form flues, and (4) fractional checker around walls. The thickness of the checker wall is always related to the total heating surface desired, but stability demands a wall not less than 2 in. thick. Fractional checkers should be avoided. In determining proper thickness of brick, an efficiency (heat-storage factor) above 95% should be chosen. Heat capacity of the stove depends on the distribution of checker brick weight from top to bottom of the stove. Graphs and tables present efficiency of checker brick, critical velocities through various openings, heat transfer by radiation and convection, and physical properties of gases and checker brick. E.H.McC.

Care of cupola refractories. C. E. Bales. *Foundry*, **63** [1] 44, 48 (1935).—Proper selection of high-grade cupola blocks and attention to operating details result in longer refractory life, more efficient cupola operation, and lower maintenance costs. Service rendered by cupola refractories depends upon the following destructive factors: (1) intense heat in the melting zone, (2) chemical erosion by the flux and slag, (3) cutting action of the blast, (4) abrasion by coming-down charges, (5) spalling, and (6) breakage loss caused by chipping out the cupola. Each of these factors is discussed with respect to the following four divisions of the cupola: (*a*) the zone above the charging door, (*b*) the zone between the charging door and the top of the melting zone, (*c*) the melting zone proper, and (*d*) the crucible. The influence of proper cupola operation upon refractory life is prominently stressed. F.G.H.

Checker brick for regenerators. Anon. *Glass*, **13** [12] 519 (1936).—The introduction of the Didier-Werke or saddle-shaped checker brick has increased the operating efficiency of the regenerators and the mechanical strength of the unit. Its shape tends to decrease the dead spaces in the regenerator and prevents the settling of dust in the checkers which ultimately chokes the unit. M.C.S.

Direct reduction of iron-containing bauxites by solid carbon materials in revolving furnaces. P. I. Dolinskiĭ. *Sovet. Met.*, **7** [1–2] 20–25 (1935).—The principal purpose of this research was the examination of the behavior of iron-containing bauxites on direct reduction in a revolving furnace. The bauxites examined were of the following composition: SiO_2 3.48, TiO_2 4.64, Al_2O_3 51.25, Fe_2O_3 29.76, MnO 0.40, S 0.10, P 0.27, volatile matter 11, and hygroscopic moisture 0.5%. D. calculates, theoretically, the quantity of charcoal necessary to reduce the 20.81 Fe_2O_3. To improve the process of reduction the quantity of charcoal was doubled. The reduction process and the results of the research are described. The following conditions are necessary for direct reduction of bauxites: (1) temperature of reduction 1050°C, (2) duration of reduction 2 hr., (3) quantity of charcoal to weight of bauxites 20%, (4) size of bauxite grain 1 mm., and (5) size of charcoal grain 0.5 mm. This research has established the possibility of complete and direct reduction of iron-containing bauxites. B.E.K.

Directional distribution of radiation and reflection of heat rays on technically important surfaces. E. Eckert. *Arch. Wärmewirt.*, **18** [4] 107–108 (1937).—E. gives a mathematical and graphical analysis of heat-exchange problems. See *Ceram. Abs.*, **15** [8] 253 (1936). F.P.P.

Efficient manufacture of dinas and silica brick. Anon. *Tonind.-Ztg.*, **61** [21] 246–49; [23] 270–71; [26] 293–95 (1937).—A general discussion of the economical manufacture of dinas and silica brick is given with special regard to the working of raw materials, shaping, drying, and firing in gas chamber and tunnel kilns. M.V.C.

Evolution of ceramics. Alix Cornille. *Céram., Verrerie, Email.*, **4** [3] 89–94 (1936).—C. discusses the progress realized in ceramics, chiefly in refractories, whose classification is given. M.V.C.

Flux; reduction experiments with iron-rich bauxites. J. Széki and A. Romwalter. *Magyar Kir. József Nádor Müszaki és Gazdaságtudományi Egyetem Bánya-, Kohó- és Erdömérnöki Kar, Sopron. A bánya és kohómérnöki osztály Közleményei*, **7**, 42–51 (1935).—Hungarian bauxites are very rich in Fe and contain appreciable amounts of Si and Ti; it is therefore difficult to separate Fe by magnetic processes, as Fe and Al are present in colloidal distribution. It seems, however, economically possible to apply a reduction with soda and carbon as iron sponge, and Al_2O_3 can be produced in one heating operation, from which Fe can be more easily separated. Experiments are described. M.H.

Furnace bottoms for tapping ash in the molten state. R. Shellenberger. *Mech. Eng.*, **58** [1] 30–34 (1936).—More than 80 slag-tap furnaces are in service, operating on coals with ash-fusion temperatures ranging from 1900 to 2550°F. Water-cooled floor tubes, bedded in and covered with a plastic chrome refractory, provide an efficient form of furnace bottom for slag-tap furnaces. Illustrated. F.G.H.

Gas-fired tilting crucible furnace. Industrieofenbau G.m.b.H. *Metal Ind.* [London], **49** [15] 360 (1936).—Attached to the furnace body are two wrought-iron arms with hooks for carrying the ladle shank, which renders it

possible for one man to pour the metal into the ladle. The gas consumption is economical with a hot start:

Metal	Gas/100 lb. (cu. ft.)	Melting time for 200-lb. charge (min.)
Gunmetal	455	50
Brass	420	40
Aluminum alloys	455	30

Illustrated. H.E.S.

Insulating of glass tank saves fuel; no harmful effects. JOHN KLUMPP, JR. *Ceram. Ind.*, **27** [2] 99 (1936).—Experiments with insulation at the Macbeth-Evans Glass Co., Elwood, Ind., included insulation of fire brick on recuperator stacks on one continuous tank and of the silica brick crown in the melting and working end and the flux block in the working end of a second continuous tank. Using 2½ in. of a vermiculite insulation, no harmful effects resulted, and the fuel savings of 3 to 4% made the installation pay for itself within a short time. E.J.V.

Insulating refractory brick. A. V. LEUN. *Ind. Heating*, **4** [6] 464–70 (1937).—L. explains the economical advantages of a brick which can serve both as refractory and as heat-insulating material in the construction of heating devices and discusses the factors in furnace design governing the fuel economy and fuel requirements. Comparative examples are given. M.H.

Laying up refractory. R. B. PURDY. *Power*, **79** [9] 462–64 (1935).—P. discusses and illustrates construction details of various types of boiler settings. A bibliography is included. F.G.H.

Method for determining thermal conductivity of refractory materials at high temperatures. B. YA. PINES, V. YA. BILYK, AND O. M. VORONINA. *Ukrain. Nauch.-Issledovatel. Inst. Ogneuporov & Kislotouporov*, No. 37, pp. 81–111 (1936).—The method of Wilkes (*Jour. Amer. Ceram. Soc.*, **17** [6] 173 (1934)), used to determine the thermal conductivity of various refractories, is described. The values for grog, magnesite, and American and Russian silicon carbide refractories are given in a table. M.V.C.

Methods of testing tank brick. F. HESSINGER. *Sprechsaal*, **70** [16] 211–12 (1937).—The known laboratory testing methods for tank brick are ineffective in the evaluation of the brick for their behavior in operation in glass works. H. describes a method for studying tank brick and discusses its use for determining the stability and behavior of the brick under the effect of molten glass. Examples are given. The method permits comparative studies between various types of brick, even of unknown composition, which are treated in the same tank. M.V.C.

Mica schist. F. G. PERCIVAL. *Tisco Rev.* [India], **4** [2] 99–100 (1936).—Quartz schist, locally called mica schist, is quarried in Singhbhum, India, for lining the Bessemer converters in the steel works at Jamshedpur. The average consumption is nearly 2000 tons for the year, the amount available being 2 million tons. Analyses show 86 to 96% SiO_2, 1.5 to 10% Al_2O_3, and 1 to 1.14% Fe_2O_3. A.P.S.

Monolithic baffle. BURTON W. WHEELER. *Power*, **79** [4] 198–99 (1935).—Relocating and replacing tile with plastic high-temperature cement to form a monolithic boiler baffle is described and illustrated. F.G.H.

Mortar for coke ovens. I. S. KAINARSKIĬ AND V. A. BROM. *Ukrain. Nauch.-Issledovatel. Ogneuporov & Kislotouporov*, No. 39, 60 pp. (1936); abstracted in *Referat. Silikatliteratur*, **4** [4] 3991 (1937).—It was found that the introduction of clay (over 20%) into quartzite mixes affects the properties of the mix on firing. Their porosity is greatly lowered on firing to 1350°, their resistance to pressure is increased (when cold), and the volume diminished. The refractoriness of the mixes decreases with increased clay content and reaches cone 26 in mixes containing 40% clay. Mixes of quartzite, clay, and chalk sinter at 850° which allows mortars of different properties to be obtained by varying their ratio of components. The addition of water-glass decreased the sintering temperature without greatly decreasing refractoriness. The use of quartz sand instead of quartzite increased porosity and lowered adherence and expansion. The fine grinding of sand does not improve the mix. Crushed silica lowers expansion; mechanical strength and porosity are not affected by the amount of crushed silica introduced. The mixes sinter at 1350° when large amounts of silica and clay are introduced. Variation in grain size affects porosity and strength of fired mixes. Standard specifications for such mortars are given. M.V.C.

Natural steatite and its use in the manufacture of parts for various purposes. E. ALBERS-SCHÖNBERG. *Stemag-Nachr.*, No. 15, pp. 21–29 (1937); abstracted in *Referat. Silikatliteratur*, **4** [4] 3997 (1937).—The manufacture of various articles from steatite which was not given ceramic treatment and its properties are discussed. The steatite blocks are cut and shaped in the same way as wood or metal, and the articles are then calcined to redness to eliminate the chemically combined water. The composition and characteristics of raw steatite are discussed in detail. M.V.C.

Obtaining aluminum from clay. Question of raw materials. W. HORNKE. *Tonind.-Ztg.*, **61** [16] 187–89 (1937).—The metal aluminum is produced by electrolysis of alumina in melted cryolite. The method of Hall is chiefly used and is described. H. discusses the production of alumina and the alkaline methods of decomposition of Bayer and Loewig and Le Chatelier. **Methods.** *Ibid.*, [18] 211–12; [19] 225–26.—Basically there are two ways in which alumina is obtained from clays, *i.e.*, production by means of a "fused" reduction and production of aluminum salts which are later decomposed and from which alumina is obtained by precipitation. A series of patented methods are briefly discussed, including the aluminum chloride, sulfate and bisulfate, aluminum sulfite, and aluminum nitrate methods. M.V.C.

Obtaining refractory raw materials with a high alumina content by means of chemical treatment. A. S. BAZILEVICH AND E. A. GALILEEVA. *Mineral. Syr'e*, No. 8–9, pp. 47–50 (1936); abstracted in *Referat. Silikatliteratur*, **4** [4] 3914 (1937).—Kaolin fired to 980°C and treated with caustic alkali loses its SiO_2 whereby the residue yields more Al_2O_3. A table shows the results of treatment. M.V.C.

Properties of refractory brick at Chasov-yar, Semiluki, and Borowichi works. V. K. GRUZINOV. *Sovet. Met.*, No. 10, pp. 16–19 (1936).—The chemical composition and physical properties of fire brick used for the construction

of blast furnaces should satisfy certain requirements. The various physical properties of fire brick of the above mentioned works are studied. These brick have the following properties: (1) The volume of open pores for Chasov-yar brick is 5.5 to 10% in the mean, for Semiluki brick 11.5 to 13.5%, and for Borowichi brick 12.5 to 14.5% in the mean. (2) The total porosity of Chasov-yar brick is 11.5 to 19.5%, of Semiluki brick 23 to 25%, and of Borowichi brick 24.5 to 27.5% in the mean. (3) In respect to chemical composition, the Semiluki and Borowichi brick Al_2O_3 content is 37 to 40%, and that of Chasov-yar brick is 32 to 36%. The content of Fe_2O_3 in all these brick varies from 1.5 to 2.5%. B.E.K.

Reactions in solid state between magnesium oxide and iron oxide. B. Ya. Pines and V. Ya. Bilyk. *Ukrain. Nauch.-Issledovatel. Inst. Ogneuporov & Kislotouporov*, No. 37, pp. 35–58 (1936).—The properties of magnesite refractories are greatly affected by their iron oxide content. Various mixtures of iron and magnesium oxide were fired to different temperatures under oxidizing and reducing atmospheres; the mechanical strength of the products was then determined, and X-ray studies of the products were made. For the products fired in oxidizing atmosphere, the experiments show that magnoferrite ($MgO \cdot Fe_2O_3$) was formed in the solid state from the components. X-rays show also the presence of this kind of crystal. The strength of magnesite brick increases only when the iron oxide particles are infolded by the MgO particles and do not touch each other. Otherwise the iron oxide particles sinter together and lower the strength of the product. X-rays showed that the brick fired in reducing atmosphere are composed of free MgO, free FeO, and a solid solution. The parameter of the solid solution depends on concentration. To produce magnesite brick of higher strength, firing first in an oxidizing atmosphere and then in a reducing atmosphere is recommended. It is important because the transformation of the ferric form of the iron into the ferrous oxide will increase the thermal stability of the brick. M.V.C.

Refractories for boilers. R. B. Purdy. *Power*, **79** [9] 458–60 (1935).—Slags are of two general types as follows: (1) those that adhere to the wall, forming a coating of increasing thickness, and (2) those that flow over the wall, leaving only a thin coating. Slags of the first type damage the refractory only when they are removed during cleaning. The flowing slag of the second type usually combines with the refractory and corrodes or erodes the wall. Refractory materials used in boiler furnaces to meet the service conditions outlined are fire clay, kaolin, diaspore, kyanite, silicon carbide, and chromium. The chemical and physical properties of each of these refractory materials are briefly described. P. discusses the importance of the load-carrying ability and resistance to spalling of the various refractories and emphasizes the importance of a careful evaluation of all the factors involved in the selection of a refractory material for a specific installation. F.G.H.

Refractories with a high grog content from Latnynkil clays. V. A. Rybnikov. *Keram. & Steklo*, **13** [4] 26–28 (1937).—Experiments showed that (1) refractories with a high grog content but without "foreign" admixtures have a great thermal resistance, low porosity, high mechanical strength, and high temperature of softening; (2) the addition of apatite concentrate greatly lowers the thermal resistance, increases mechanical strength, and lowers refractoriness and temperature of softening under load; (3) this low thermal resistance of grog brick containing apatite is greatly increased by adding 3 to 9% powdered silicon carbide; (4) such refractories have an exceptional thermal resistance, low porosity, and high mechanical strength and refractoriness under load. M.V.C.

Refractory developments. R. B. Purdy. *Power*, **79** [9] 460–61 (1935).—P. describes improvements in grinding, screening, mixing, pressing, drying, and firing. F.G.H.

Requirements placed by metallurgy on chromite used as a refractory material. J. I. Dolitzkiĭ. *Sovet. Met.*, No. 10, pp. 12–15 (1936).—The refractoriness of chromite increases with the Cr_2O_3 content. The melting point of $FeO \cdot Cr_2O_3$ is 2180°, of natural chromite used for clay work 1900° to 2050°C, and of chromite brick 1700° to 1950°C. In metallurgy these brick are principally used to cover the working room of the open-hearth furnaces and of the basic converter and for hearthstones of heating furnaces. The chromite brick resist corrosion, but they are subjected to mechanical erosion. The natural chromite used to cover the open-hearth furnaces should be of an amorphous texture and sufficiently massive. The minimum weight of the lump of natural chromite should be 15 kg. For blocking up of outlets of the furnaces it is necessary to use pure, powdery massive chromite. The content of Cr_2O_3 in the chromite is also of great importance and should be 38 to 40% or more. Chromite is unaffected by slags of any composition. D. describes various types of chromite and chromite-magnesite brick such as Chromodur, Radex E, Chromite I and II, Fournal, Rubinit, and Siemensite. Siemensite has a melting point over 2000°C, is unaffected by any slag, and is economical. The production of chromite-magnesite brick with a high content of Al_2O_3 is recommended. B.E.K.

Saggers and their life. R. Makhl. *Keram. & Steklo*, **13** [4] 32–35 (1937).—Because of a large shortage of saggers for porcelain ware in Russia, general directions for the manufacture of saggers are given. Composition and characteristics are given in a table. M.V.C.

Savings with insulating refractories. J. G. Coutant. *Chem. & Met. Eng.*, **44** [3] 137 (1937).—Insuline, made by expanding fire clay, is used in producing refractory concrete and insulating refractories. Insulating refractories weigh from 30 to 37 lb./cu. ft. Through proper insulation, fuel savings have been marked, especially in intermittent furnaces; the furnaces are more responsive to temperature control, heat up rapidly from a cold start, store a relatively small amount of heat in the walls, and cool down rapidly when the fire is shut off. See "Economic—," *Ceram. Abs.*, **16** [1] 21 (1937). M.C.S.

Service of plug tubes. D. Smirnov. *Sovet. Met.*, No. 9, pp. 56–59 (1936).—The strongest tubes have the following composition: fire clay 40% fired at 1300°C, clay 60%, moisture of the mass at pressing 20%, and moisture of tubes on loading in the furnace 3%. B.E.K.

Silica brick of improved characteristics (refractoriness and softening under load) for electric furnaces. I. S. Smelyanskiĭ. *Ukrain. Nauch.-Issledovatel. Inst. Ogneuporov & Kislotouporov*, No. 41, 62 pp. (1937); abstracted

in *Referat. Silikatliteratur*, **4** [4] 3980 (1937); see "Electrodinas," *Ceram. Abs.*, **16** [4] 119 (1937). M.V.C.

Silica brick from the Ovruch quartzites. G. B. TAUBIN. *Ukrain. Nauch.-Issledovatel. Inst. Ogneuporov & Kislotouporov*, No. 40, 64 pp. (1937); abstracted in *Referat. Silikatliteratur*, **4** [4] 3972 (1937).—Sample brick prepared from these quartzites were fired for 60 hr. up to 1460°C. Their characteristics were as follows: (1) water absorption 5 to 6.7%; (2) porosity from 17 to 24%; (3) resistance to pressure when cold, from 206 to 600 kg./sq. cm.; (4) refractoriness 1710 to 1750°C; and (5) softening temperature 1650 to 1695°C. Conclusions are that Ovruch quartzites are excellent raw material for silica brick and that silica brick manufactured from them answer all specifications for open-hearth steel furnaces. M.V.C.

Small refractory crucibles for laboratory work. M. RIDDIHOUGH. *Iron & Steel Ind.*, **10** [5] 241 (1937).—For small crucibles of highly refractory nature, R. finds that a satisfactory material is fused crushed Alundum used for abrasive wheels. It contains sufficient flux to melt at approximately 1600°C which bonds it thoroughly. Crucibles made of such 90-mesh Alundum are satisfactory for melting steel but are porous and readily absorb slag. Porosity is reduced one half by using 45% "flour" grade. R. gives the formula for determining porosity and illustrates and describes molds of his own design. Molds are lined with thin paper to prevent the refractory from sticking to the walls. E.H.McC.

Suspended walls and arches. R. B. PURDY. *Power*, **79** [9] 465–67 (1935).—Suspended refractory walls offer several advantages over solid refractory walls. Although first cost is higher, repairs are lower because less refractory has to be replaced and the work can be done more easily and quickly. The refractory carries less load; hence, it can operate at higher temperatures, and more positive means for expansion are provided. Suspended walls are designed so that they may be used either as air-cooled walls, insulated walls without air cooling, or as insulated refractory walls behind bare-tube water walls. P. discusses and illustrates several features of suspended-wall construction which must be investigated when such walls are considered. These features apply also to suspended arches such as those used for chain-grate stokers. They may be classified under the two following headings: (1) features affecting installation and repair, and (2) features affecting wall performance. F.G.H.

Used refractories. C. C. HERMANN. *Power*, **79** [10] 533 (1935).—H. describes the use of crushed refractories in combination with high-temperature cement to yield a refractory patching material. F.G.H.

Water-cooled walls. R. B. PURDY. *Power*, **79** [9] 468–69 (1935).—P. describes and illustrates typical examples of wall and slag-tap furnace bottom construction used with water cooling. F.G.H.

X-ray method for quantitative determination of crystals in refractory materials. B. YA. PINES. *Ukrain. Nauch.-Issledovatel. Ogneuporov & Kislotouporov*, No. 37, pp. 59–79 (1936).—The sample in which the crystalline compound is to be determined is crushed and mixed with definite amounts of comparison material, and X-ray pictures of the mixtures are taken. Common salt was found to be good comparison material. Details of procedure are given. The mullite content of various technical mullites and sillimanites was determined in this way. For comparison purposes the mullite content was also determined analytically by disintegrating with hydrofluoric acid. X-ray determination always shows a somewhat higher mullite content than the chemical analysis as HF dissolves part of the mullite. Analysis of pure mullite showed that solid solutions of mullite type are present in the silica-alumina system, and their chemical composition varies. The content of chromite, periclase, or silicon carbide can be determined in refractories according to this method. The error in X-ray determination does not exceed 6%. M.V.C.

SEPARATE PUBLICATION

Refractory materials for checker brick for regenerative glass furnaces. O. BARTSCH AND J. LAMORT. *Fachausschussber.* (Deut. Glastech. Ges.), No. 34, 14 pp. (1935); abstracted in *Referat. Silikatliteratur*, **4** [4] 3843 (1937).—The following refractories are used: (1) Acid brick: lime-bonded quartzite brick (silica and dinas brick) containing 95 to 97% SiO_2 and clay-bonded quartzite brick (clay quartz and clay dinas) with 90 to 95% SiO_2. (2) Semiacid brick: clay brick, quartz-grog brick (13 to 25% SiO_2). (3) Grog brick poor in Al_2O_3 (20 to 27%), with average content of Al_2O_3 (28 to 35%), and rich in Al_2O_3 (36 to 44%). (4) Special refractories: bauxite, sillimanite, mullite, corundum, magnesite, chromite, zirconium, and silicon carbide brick. Grog brick are mostly used with an Al_2O_3 content from 18 to 45%. Silica brick are rapidly destroyed by flue dust and evaporating glass constituents through the formation of a glaze. Semiacid brick and grog brick do not always resist operating conditions. The resistance to temperature variations of chamber brick does not need to be high. Slate clay brick with over 40% Al_2O_3 are the most resistant. Brick with increasing Al_2O_3 tend to form a fur-like formation because of flue dust which clogs the flues. In each case the use of a particular brick should be determined experimentally. Gas-chamber brick should contain the least possible amount of iron compounds which can be reduced in order to keep the carbon deposition as low as possible. Severely fired brick are generally preferred. See *Ceram. Abs.*, **12** [12] 424 (1933). M.V.C.

PATENTS

Basic refractory. C. E. WILLIAMS AND J. D. SULLIVAN (Battelle Memorial Institute). Can. 366,300, May 25, 1937 (Jan. 30, 1936). Comprising the solidified product of a molten mass comprising magnesium oxide and at least one other basic material which has a lower melting point than magnesium oxide. G.M.H.

Cast refractory manufacture. R. C. BENNER (Carborundum Co.). Can. 365,450, April 20, 1937 (March 27, 1935). See *Ceram. Abs.*, **16** [2] 65 (1937). G.M.H.

Ceramic composition. J. B. STÅLHANE. U. S. 2,086,828, July 13, 1937 (March 18, 1936). A bonding agent for refractories consists of a mixture of substances containing a high percentage of aluminium oxide (Al_2O_3) with arsenic compounds having the quality of forming arsenate of aluminium by slight heating.

Chrome-magnesia refractory and method. R. P. HEUER (General Refractories Co.). U. S. 2,087,107,

July 13, 1937 (June 29, 1936). In the manufacture of refractory brick suitable for use without previous kiln firing, the process comprises mixing from 65 to 75 parts of larger particles consisting chiefly of chrome ore and large enough to be retained on a 20-mesh per linear inch screen with from 35 to 25 parts of smaller particles consisting chiefly of magnesia and small enough to pass through a 50-mesh per linear inch screen, and with a bonding substance, molding the mixture into brick under pressure exceeding 1000 lb./sq. in., and treating the brick without kiln firing to develop the bond.

Chromite refractory. G. E. Seil (E. J. Lavino & Co.). Can. 366,039, May 11, 1937 (Sept. 21, 1936). See "Process—," *Ceram. Abs.*, **16** [2] 65 (1937). G.M.H.

Furnace wall. M. H. Kuhner and G. A. Rehm (Riley Stoker Corp.). U. S. 2,086,940, July 13, 1937 (Nov. 4, 1935).

Muffle plate. Robert Kirkpatrick (Norton Co.). U. S. 2,086,504, July 6, 1937 (March 5, 1936).

Production of alumina practically free from silicic acid from alkaline-earth aluminates. Lonza Elektrizitätswerke und Chemische Fabriken Akt.-Ges. Brit. 466,919, June 23, 1937 (Jan. 11, 1936).

Refractory. C. L. Norton, Jr. (Babcock & Wilcox Co.). Can. 366,794, June 15, 1937 (April 7, 1936). A method of inducing the formation of mullite crystals in a fired silica-alumina article at low temperatures consists of mixing with the base material a soda-lime glass of substantially silica, 70 parts by weight, soda, 15 parts, and lime, 15 parts, and heating the whole until the formation of mullite and glass has progressed sufficiently to give the article requisite strength. G.M.H.

Refractory ceramic bodies containing titanium dioxide. Steatite & Porcelain Products, Ltd., and J. A. Sugden. Brit. 467,113, June 23, 1937 (Dec. 10, 1935).

Refractory cooling method. G. J. Easter (Carborundum Co.). Can. 364,422, March 2, 1937 (March 20, 1935). A method of forming refractory castings composed essentially of at least two parts of corundum to one part of mullite in a glassy matrix. G.M.H.

Terra Cotta

Architect looks at clay. Theodore Irving Coe. *Bull. Amer. Ceram. Soc.*, **16** [7] 277–79 (1937).

Differences between crockery and fireclay ware. M. Reitz. *Keram. Rundschau*, **44** [49] 583–84 (1936).—The differences of raw materials and manufacture are dealt with. R. advocates the following slip: 25 plastic clay, 20 plastic kaolin, 10 feldspar, 45 fired fire clay (1 to 3 mm. each one third). Per 100 kg. dry weight he recommends 29 kg. water, 65 g. Na_2CO_3, 48 g. NaOH, and 28 g. tannin. This slip, with such a small amount of water and electrolytes, holds fired clay perfectly in suspension. The granulometry of body and engobe is given. Fireclay ware is normally fired in one heating only. F.E.V.

Pumps for acids. Anon. *Tech. Blätter*, No. 6, pp. 76–77 (1937); abstracted in *Tonind.-Ztg.*, **61** [14] 174 (1937).—Various types of pumps for handling acids are described. The use of acid-stable stoneware instead of acid-stable metals and alloys is recommended. Resistance to pressure of stoneware exceeds even that of cast iron and its tensile strength has lately been greatly increased. Stoneware is completely resistant to all acids with the exception of hydrofluoric acid; it is also resistant to temperature variations. M.V.C.

Salt glaze. Anon. *China, Glass & Lamps*, **56** [8] 39 (1937).—Germany should receive credit for introducing salt glaze. It was used there on stoneware during the 16th Century. The method of discovery is not known. Salt glazing reached its highest perfection in Staffordshire, Eng. It was believed to have been introduced by the Elers brothers who came to Staffordshire from Saxony, established a pottery, and did much to improve English pottery. G.M.P.

PATENTS

Roofing tile. E. Swingler. Brit. 467,622, June 30, 1937 (April 23, 1936).

Soil and masonry impermeabilizing process. Jan van Hulst and G. H. van Leeuwen (Patent and Licensing Corp.). Can. 366,465, June 1, 1937 (June 5, 1935). G.M.H.

Whiteware

Application of porcelain and other ceramic insulating materials in electrical engineering. W. Steger. *Elektrotech. Z.*, **57** [17] 471–76 (1936).—S. gives a comprehensive, illustrated survey of the use of ceramic materials as insulators. The following groups of materials are discussed: porcelains, talc-base materials, and rutile-containing compounds. Thermal, mechanical, and electrical properties and individual applications are discussed. F.P.P.

Attempts to determine the tensile strength of steatite rods. K. Schandinn. *Stemag-Nachr.*, No. 15, pp. 3–18 (1937); abstracted in *Referat. Silikatliteratur*, **4** [4] 3982 (1937).—Tests showed that steatite insulators do not show any signs of aging and fatigue as does steel. Results are tabulated. M.V.C.

Casting slip difficulties. E. Wettig. Translated in *Ceram. Ind.*, **27** [3] 187 (1936); see *Ceram. Abs.*, **15** [10] 306 (1936). E.J.V.

Faience factories established near the city of Rouen. Bollioud. *Céram., Verrerie, Email.*, **4** [4] 165–68; [5] 207–13 (1936).—The faience ware of Rouen is esteemed for its perfect workmanship, beauty of color, and tasteful design. B. discusses (1) the choice of clays in the manufacture of faience at Rouen and their preparation; (2) the composition of the enamel and the manner of its application; (3) colors; and (4) firing. M.V.C.

Fluorspar, its possibilities in the ceramic industry. C. W. Parmelee. *Ceram. Ind.*, **27** [3] 196–200 (1936).—Tests on sanitary ware and semivitreous bodies showed that small additions of fluorspar had a beneficial effect because the mechanical strength was increased, the thermal expansions were somewhat lowered, translucency was in-

creased, and vitrification could be accomplished at a lower temperature. Only in thermal shock tests were the fluorspar-containing bodies inferior. E.J.V.

Lead frits and fritted glazes. J. H. KOENIG. *Ceram. Ind.*, **27** [2] 108–12 (1936).—Lead frits as now supplied for glaze formulation are poorly resistant to dilute acid attack. Alumina strongly decreases acid solubility of lead while alkalis and boric oxide increase it. Effects of the various oxides on solubility are presented. See *Ceram. Abs.*, **15** [10] 306 (1936). E.J.V.

Magnesite putty for porcelain insulators. M. A. TRAKHTENBERG. *Novosti Tekhniki (Mashinostroenie)*, No. 54, pp. 14–16 (1935).—The batch of this putty contains magnesium oxide, a water solution of magnesium chloride, asbestos, wood sawdust, silicon carbide, sand, etc. In order to decrease the high coefficient of linear expansion of the putty, it is necessary to add porcelain meal. The production process of the insulators and the results of their mechanical tests are described. The following composition of putty guarantees the highest quality of these insulators: 28% magnesium oxide; 44% water solution of magnesium chloride (28°Bé), and 28% porcelain meal, screened through 900 mesh/cm.^{2} The casting of insulators must take place 2 hr. after the mixing up of the batch. B.E.K.

Pottery manufacture. A. S. W. ODELBERG. *Trans. Ceram. Soc.*, **36** [2] 56–62 (1937).—O. discusses some of the technical aspects of pottery manufacture in Sweden and stresses the importance of maintaining technical, artistic, and economic departments of equal strength. R.H.H.P., JR.

Production of electrical porcelain. R. RIEKE. *Elektrotech. Z.*, **57** [17] 469–70 (1936).—R. gives a general description of manufacturing operations together with a detailed flow sheet. Sorting and testing methods are described. F.P.P.

Spontaneous rupture of aged pottery. J. W. MELLOR. *Trans. Ceram. Soc.*, **36** [1] 10–12 (1937).—The spontaneous rupture of an 8 yr. old bone china plaque and an 18th Century Imari dish are given as examples of radial cracking in circular slabs. During the aging of ware, delayed thermal contraction will induce internal concentric strain lines; the slow intensification of these strains may ultimately make them too great for the body to bear and rupture ensues. R.H.H.P., JR.

Substitution of domestic for imported clays in whiteware bodies. WILLIAM W. MEYER AND THERON A. KLINEFELTER. *Jour. Research Nat. Bur. Standards*, **19** [1] 65–79 (1937); R.P. 1011. Price 5¢.—Domestic kaolins and ball clays were substituted for imported clays in whiteware bodies of the more important types. The substitutions were based on compositions, in terms of RO, RO_2, and R_2O_3, of the bodies and raw materials and on physical properties of the raw materials and those required of the bodies. Laboratory tests of dried and heat-treated specimens indicated that the properties of imported clay bodies could be duplicated by domestic clay bodies, and factory tests showed that in most cases this would involve only minor changes in plant procedure. The vitrification temperatures of whiteware bodies were correlated with their RO contents. The plasticities and the strength of the dry specimens depended chiefly on the ball-clay contents of the bodies. The RO and ball-clay contents can be varied widely with little effect on the physical properties of whiteware bodies heated to the same degree of vitrification. R.A.H.

Summation of whiteware research investigation conducted at New York State College of Ceramics. ROBERT M. CAMPBELL. *Bull. Amer. Ceram. Soc.*, **16** [7] 294 (1937). **I, Production of a light yellow-green body stain for a cone 10½ vitreous body.** ROBERT E. COOLEY, JR. *Ibid.*, pp. 294–95. **II, Effect of vitreous whiteware grog in a vitreous whiteware body.** CHARLES E. EVANS. *Ibid.*, pp. 295–96. **III, Substitution of cristobalite for quartz in a whiteware body.** PHILLIP M. BENNETT. *Ibid.*, p. 296. **IV, Production of a cone 4 single-fire wall-tile body high in pyrophyllite.** LEE M. HEDGES. *Ibid.*, pp. 296–98.

Test for differentiating ceramic products of faience and porcelain by the use of the differential dilatometer of M. P. Chevenard. MARC LARCHEVÊQUE. *Céram., Verrerie, Email.*, **4** [3] 95–98; [4] 141–46 (1936).—To compare and distinguish between fine ceramic products with a body of vitrified paste and those with a porous paste body, the differential dilatometer method with mechanical recording is simpler, shorter, and more exact than other methods, such as the measurement of porosity or hardness. The precision of this method, contrary to other methods, permits the exact differentiation between very similar products, such as fine, extra-hard, hard, and ordinary faïence, or true and pseudo porcelain and hybrid products. The principle of the differential dilatometer consists in registering mechanically or photographically the difference in expansion between a trial specimen of Pyros metal (standard of temperature), formed by a special alloy with regular thermic and perfectly reversible properties, and a test piece in the form of a parallelepipedal rectangle of 65 mm. length and 5 x 5 mm. section cut in the product to be studied or shaped in the same way and with the same material as the latter. The differential dilatometer curve described on the photoplate by the luminous point image or by the pen on the end of the needle of the mechanical recorder, when the two specimens expand, represents (1) the ordinates (the difference of expansion between the trial piece of standard metal (Pyros) and the specimen of the product to be tested); and (2) the abscissas (the expansion of the standard in relation to fused silica, *i.e.*, the temperature). To obtain from the original curves given by the apparatus the curves permitting reading of the expansion value directly at each temperature, it is necessary either to add or subtract the recorded expansions from the expansion of the Pyros, according to whether the curve inscribed is above or below the longitudinal axis passing by the origin. It was evident from both practice and theory that the expansion curves, from 0 to 1000°, of products with a vitrified body should be different from porous products which are less resistant, permeable, opaque, and have lower density. The principal point of comparison, besides the importance of their expansion from 900 to 1000°C, is the inflexion which the curves of products with a porous body occasionally present between 550 and 600°, while products with a semivitrified or completely vitrified body have practically no inflexion. Graphs of curves for different fine ceramic products are given and analyzed. M.V.C.

Tests for ceramic products. PIERRE RENAULT. *Céram., Verrerie, Email.*, **4** [7] 269–77 (1936).—R. describes physical tests on the apparent density, cohesion and tenacity, rupture by flexion and shock, reflecting power, and structure and presents in tables data on the properties of French and other makes of fine ceramic ware. Quick chemical tests for the rapid differentiation or classification of several fine ceramic products are given. M.V.C.

BOOK

Liverpool and Her Potters. H. BOSWELL LANCASTER. Jones & Co., Ltd., Liverpool. Price 5s. L. gives a description of many potteries which at various times operated in Liverpool, including an alphabetical list of their names, addresses, chief productions, and some details of their methods of trading, patterns, etc. Several gaps in the existing literature are filled by this book. A.B.S.

PATENTS

High-voltage insulator. B. A. PLIMPTON (Locke Insulator Corp.). U. S. 2,084,866, June 22, 1937 (July 3, 1935).

Means for supporting and placing pottery, etc., during firing processes. W. E. MADDOCK. Brit. 467,373, June 30, 1937 (June 18, 1936).

Equipment and Apparatus

Accurate orientation of thin sections. EARL INGERSON. *Amer. Mineralogist*, **22** [6] 760–72 (1937).—With the advent of petrofabric analysis has come the necessity for accurate measurement and recording of orientations of thin sections with respect to geographic directions, structures in rocks, or both. I. describes and illustrates his apparatus, devised for the purpose of orienting hand specimens accurately in the laboratory, measuring the orientations of the joints, s-planes, and lineations, and marking planes of thin sections. F.J.Z.

Application of heat-resisting alloys to the pottery industry. ANON. *Nickel Bull.*, **10** [4] 77–80 (1937).—Although no alloys commercially available will withstand the temperatures of the highest pottery kilns (1300°C), some nickel alloys have been developed which are serviceable in the glost and enamel kilns. Illustrations are given of a truck for a tunnel kiln with nickel-alloy bats, a circular decorating kiln showing alloy superstructure, and a diagram of clay stilts incorporating alloy supporting and reinforcing rods. Sand seal plates, flue dampers, kiln doors, fire bars, etc., are likely cases for the correct alloy. H.H.S.

Automatic temperature controller for coal-fired installations. FOSTER INSTRUMENT CO. *Metal Ind.* [London], **48** [7] 220–21 (1936).—An automatic temperature controller designed to be used with coal stokers is described and illustrated. H.E.S.

Ball mills for wet grinding; their correct and incorrect application. O. PROMNITZ. *Farben-Ztg.*, **41** [6] 136–37 (1936).—**Ball mills for the finest wet grinding.** *Ibid.*, **41** [31] 770–71.—A practical discussion of ball-mill operation, particularly for the pulverizing of lacquer colors, is given. Size of the balls is important as too small a milling surface with excessively long milling time results from using small balls. Other factors to be considered for correct milling include the amount of free space in the mill (methods for the calculation of which are given), the shape of the ball mill, and the consistency of the milled material. F.P.P.

Calibration of partial radiation pyrometers. H. JEBSEN-MARWEDEL. *Glastech. Ber.*, **13**, 416–20 (1935); reprinted in *Arch. Wärmewirt.*, **17** [7] 189–90 (1936). F.P.P.

Calibration of testing machines under dynamic loading. BRUCE WILSON AND CARL JOHNSON. *Jour. Research Nat. Bur. Standards*, **19** [1] 41–57 (1937); R.P. 1009. Price 10¢.—The errors of the indicated loads of testing machines used to determine the mechanical properties of engineering materials are usually determined for static loads. Testing machines are often used to load specimens continuously to failure at a given rate of loading. The additional errors, due to rate of loading, of six testing machines comprising four types widely used in this country were determined by means of a special elastic calibrating device for rates of loading up to 50,000 lb./min. The additional errors in the indicated loads of these machines, due to rate of loading, at rates currently used in testing, exceeded in several cases the tolerances specified for such testing machines. R.A.H.

Clay refining by flotation methods. M. C. SHAW. *Bull. Amer. Ceram. Soc.*, **16** [7] 291–94 (1937).

Colloidal graphite and its rôle in the ceramic industry RAYMOND SZYMANOWITZ AND BERNARD H. PORTER. *Bull. Amer. Ceram. Soc.*, **16** [7] 282–88 (1937).

De-airing clay bodies for flowerpots. ANON. *Ceram. Ind.*, **26** [6] 419 (1936).—The Cleveland Pottery, manufacturer of flowerpots, has found since installing a Fate-Root-Heath de-airing machine that its kiln losses have been reduced and the green ware is tougher, though the workability of the clay has been decreased slightly. Changes in the driers to reduce drying losses are described, as is the firing procedure used. The vacuum used averages 27 in. Results are better with a higher vacuum, and below 25 inches the results are practically the same as with an unevacuated clay. E.J.V.

Drying and driers. KARL EICKHOFF. *Arch. Wärmewirt.*, **17** [6] 153–58 (1936).—E. reviews the mechanism of drying, the use of Müller-Höhn and Mollier diagrams, drying equipment, and several typical examples of moisture removal problems. F.P.P.

Drying granular solids. NORMAN H. CRAGLSKE AND O. A. HOUGEN. *Ind. Eng. Chem.*, **29** [7] 805–13 (1937).—The drying rate of a granular substance is determined not by diffusion but by capillary forces. The investigation should be extended to include the effect of position, of vertical and horizontal surfaces, and of substances of high capillarity where equilibrium moisture content is appreciable. Illustrated. F.G.H.

Drying properties of clays: I, Effect of small imposed loads on the rate of drying of some clays. II, Effect of small imposed loads on shrinkage behavior and plastic

properties of some clays. III, Influence of pallets on the quality of clay products. H. G. SCHURECHT AND C. MAJOR LAMPMAN. *Jour. Amer. Ceram. Soc.*, 20 [8] 266–81 (1937).

Fast and thorough method for impregnating porous rocks. R. VON HUENE. *Econ. Geol.*, 32 [3] 387–88 (1937).—In the method described, the rock is first ground to the dimensions of the slide and the surface which is to be next the glass is finished as well as the texture of the rock will allow. It is then dried at 120°C on a hot plate. When thoroughly dry it is dipped in a xylene solution of balsam (about 5% balsam). This thin solution readily enters the pores. Heating again on the hot plate quickly evaporates the xylene, leaving a thin coating of balsam along the walls of the pores. As soon as the balsam on top of the section reaches the snapping point, the dipping is repeated. Alternate dipping and heating is continued until the balsam forms a solid cover on top of the rock. Since the balsam layer around the pore walls is built up gradually, it fills the pores completely and is of the same hardness throughout the rock. After impregnation, the surface which was ground flat is prepared carefully for mounting. Soft wall tile can be impregnated evenly to a thickness of $^1/_4$ in. in about 20 min. J.L.G.

High-temperature measurement with a new optical pyrometer. K. GUTHMANN. *Arch. Wärmewirt.*, 18 [2] 49–52 (1937).—G. describes the construction of a new optical pyrometer, claimed to avoid the customary errors due to assumption of black body radiation from the hot material and giving directly the true temperature with brightness correction, and cites examples of its application. F.P.P.

Improvements in tungsten-wound furnaces for high temperatures. H. CIECIORRA AND W. DAWIHL. *Keram. Rundschau*, 44 [15] 171–72 (1936).—Furnaces with inner and outer tungsten spools are described. In the case of furnaces with inner resistors, it is possible to concentrate the spirals at both ends and increase substantially the zone of constant temperature. The substitution of rammed refractory clay for a fired body accelerates the construction of furnaces. The use of alumina tubes with external tungsten resistors allows heating in oxidizing conditions up to 1800°C. The employment of zirconium or beryllium oxide tubes would permit a somewhat higher efficient temperature. Illustrated. F.E.V.

Influence of the solid on the flow properties of dilute suspensions. R. N. TRAXLER. *Chem. & Met. Eng.*, 44 [4] 200 (1937).—In studies involving the viscosity or flow properties of dilute suspensions it is sometimes necessary to determine the size, shape, and size distribution of the particles in suspension, since these factors influence the void size of the system and since the viscosity of a liquid-solid system appears to be inversely proportional to the average void size. It is pointed out that the average void size can be calculated from the permeability of the compacted, unconsolidated powder under consideration and that an empirical relationship exists between the per cent of voids and the average void size. See "Viscosities—," *Ceram. Abs.*, 16 [7] 224 (1937). M.C.S.

Instrument for the exact measurement of large elongations. J. PIRKL AND T. POVSCHE. *Mitt. Tech. Versuchsamtes*, 25, 4–11 (1936).—The defects of usual methods and instruments in measuring large elongations are pointed out, and a new indicating device, with rollers instead of knife bearings, is described which permits measurement of elongations up to 4 mm. with an accuracy of 0.001 mm. M.H.

Measurement of particle-size distribution by optical methods. Effect of light of different wave-lengths. H. E. SCHWEYER. *Ind. Eng. Chem., Anal. Ed.*, 9 [5] 211–12 (1937).—Illustrated. F.G.H.

Mechanism of flotation. Adsorption on the particles of an aqueous suspension of talc, and its flotation. Z. W. WOLKOWA, N. N. SERB-SERBINA, AND A. W. SAPOROSHEZ. *Kolloid-Z.*, 71 [2] 230–34 (1935).—The adsorption of isovaleric acid on talc particles suspended in water is studied; transformation of the crystal lattice of talc occurs, Mg ions going into the solution and being replaced by H ions. Optimum flotation conditions obtain when the concentration of isovaleric acid is 0.5%. The observed coagulation is ascribed to peptization of the particles of the hydrophobic powder by excessive concentration of the reagent. F.P.P.

Method of measuring higher resistances. H. GÖNNINGEN. *Elektrotech. Z.*, 58 [12] 316–18 (1937).—An electrostatic method is described that permits measurement of resistances as great as 10^{14} ohms using voltages between 100 and 200 v. Its application to small condensers and insulating fats and oils is illustrated. F.P.P.

Operating experience with vacuum presses. WIEDEMANN. *Tonind.-Ztg.*, 61 [22] 257–58 (1937).—W. discusses the use of a vacuum press in the manufacture of hollow brick. The defects of construction of the press and measures taken to eliminate them are dealt with. M.V.C.

Plant experience with vacuum presses. TRETTNER. *Tonind.-Ztg.*, 61 [20] 235–36 (1937).—T. describes results obtained when using a vacuum press in the manufacture of roof tile, face brick, and hollow ware. M.V.C.

Portable induction furnace. INDUSTRIE ELECTROÖFEN G.M.B.H. *Metal Ind.* [London], 49 [15] 359–60 (1936).—An induction furnace of the portable type operates in conjunction with a water-cooled chill mold. Neither crucible nor heating elements are required, and the furnace lining, which is in direct contact with molten metal, is claimed to have a minimum life of at least 3000 heats. For melting aluminum, the current consumption is 360 kw.-hr./ton, but one of the greatest advantages is the low melting loss, 0.8%. Illustrated. H.E.S.

Pulverizing processes. A. H. M. ANDREASEN, B. WESENBERG, AND E. GRUE JESPERSEN. *Kolloid-Z.*, 78 [2] 148–56 (1937).—Plate glass, feldspar, and a whiteware body were crushed by pressure and by impact methods, and distribution of the particles according to size was obtained by screening and by settling. Pressure crushing was performed with a 5-ton hydraulic press and impact crushing with a mechanical hammer, both under carefully controlled conditions. Larger particles were counted and weighed, while the finest particles were suspended in ethylene glycol in A.'s previously described apparatus, and their sizes calculated from Stoke's law. The results are tabulated and plotted to show that (1) on a given material, size distribution was apparently unaffected by the method of crushing, (2) the smallest particles came from the center

of the powdered material, and (3) increase in crushing pressure or impact force produced a finer powder. The theoretical mechanism of comminution is discussed. F.P.P.

Radiation allowances for heat transfer inside tubes. P. Koessler. *Arch. Wärmewirt.*, **17** [1] 17–18 (1936).—K. gives useful diagrams for calculating the heat radiated from hot gases and flames within tubes. F.P.P.

Reliability of common types of thermocouples. D. Quiggle, C. O. Tongberg, and M. R. Fenske. *Ind. Eng. Chem.*, **29** [7] 827–30 (1937).—For the temperature range covered, for the size of wires, and for the conditions under which the tests were made, the results obtained yield the following indications: (1) Heat treatment of copper-copel, copper-constantan, and chromel-alumel thermocouples above about 200°C causes them to indicate temperatures which are different from those before heat treatment, the discrepancy being greater the higher the temperature of heat treatment; moreover, measurements of lower temperatures show less discrepancy than measurements of higher temperatures. (2) Heat treatment of copper-copel and copper-constantan thermocouples at temperatures between about 200°C and 300° to 350°C causes them to indicate a higher temperature than before such heat treatment; heat treatment above 300° to 350°C causes them to indicate a lower temperature. It may be concluded that copper-copel and copper-constantan thermocouples possess a rather high degree of reliability if used in the temperature range 0° to 200°C. Illustrated. F.G.H.

Testing for weatherproofness of materials by means of the so-called crystallization test. Annemarie Schmölzer. *Mitt. Tech. Versuchsamtes*, **25**, 14–20 (1936).—The best method to imitate the natural conditions in destruction of materials by effects of weather consists in immersing the material in a solution of Na_2SO_4 in $10H_2O$ and drying at different temperatures. The crystals growing from the solution retained in the interior of the material exert, by their change of volume, an effect similar to freezing water, and the destructive action can easily be followed. The application of the method is illustrated by the example of several rocks and minerals. M.H.

Tirustor control. Application to electroplating and glass annealing. Anon. *Electrician*, **118** [3076] 660 (1937).—A photograph is shown of the equipment attached to a glass annealing furnace. The apparatus is a door opener which is worked by the operator standing on a foot bar. By this means the furnace door is opened and closed smoothly without the operator putting any hand thereon. It is evidently used for batch annealing. H.K.R.

Two approved connections of X-ray universal apparatus for testing materials. F. Regler. *Mitt. Tech. Versuchsamtes*, **25**, 20–31 (1936).—On the basis of theoretical discussion of the principles for the examination by X-rays of coarse structure and fine structure and for X-ray spectroscopy, R. describes a stationary and a portable installation of an X-ray apparatus which can be used equally well for these purposes. Voltages up to 200 kv. are used. M.H.

Washing clay out of molding sand. Anon. *Iron Age*, **139** [12] 46 (1937).—A motor-driven machine for automatically washing molding sand is described and illustrated. Water carrying the clay flows over the top of wash bottles, with flow controlled to carry sand particles of only 20 microns or smaller. A constant temperature of 750°F is maintained. E.H.McC.

BOOK AND CIRCULAR

List of permissible mine equipment. L. C. Ilsley. *U. S. Bur. Mines Information Circ.*, No. 6942. 23 pp. Free. Permissible mine equipment approved by the Bureau to Jan. 1, 1937, is listed. R.A.H.

Press Work Pressures. C. W. Lucas. McGraw-Hill Book Co., New York. 128 pp. Price $4.00. Reviewed in *Mech. Eng.*, **58** [2] 132 (1936).—This volume presents the results of over 1000 tests of the pressures necessary for various operations. It is intended to guide the engineer in estimating the size and type of press required for a given job. The information is classified according to the operation, material, shape, and size of product and is presented clearly and concisely. F.G.H.

PATENTS

Clay conditioning method. S. C. Lyons (Bird Machine Co.). Can. 365,666, April 27, 1937 (April 15, 1935). G.M.H.

Clay suspension resolution. S. C. Lyons (Bird Machine Co.). Can. 365,667, April 27, 1937 (July 13, 1936). G.M.H.

Conditioning of freshly quarried clay. S. C. Lyons (Bird Machine Co.). U. S. 2,085,537, June 29, 1937 (Jan. 18, 1935). In the conditioning of freshly quarried clay to produce a purified and marketable product, the practice comprises suspending the clay in water to produce a readily flowable suspension, progressively streaming the suspension through a centrifuge to deposit progressively under centrifugal force on its wall oversized impurities, then progressively streaming the suspension through another centrifuge, whose wall is electrically charged to attract the fine solids content of the suspension, to deposit progressively on its wall under combined electrophoretic and centrifugal forces the fine solids content as a plastic mass while substantially constantly removing the plastic mass from the wall to maintain substantially constant the combined electrophoretic and centrifugal forces acting to deposit the fine solids and thereby substantially constantly to maintain of substantially uniform average particle size the fine solids being deposited and removed as a plastic mass, and drying such removed plastic mass.

Crusher. Edward Kraemer. Can. 366,391, May 25, 1937 (March 25, 1936). G.M.H.

Crushing and mixing machine. P. B. Bucky (University Patents, Inc.). Can. 366,201, May 18, 1937 (Aug. 20, 1935). G.M.H.

Frit kiln. J. W. Emery. U. S. 2,085,254, June 29, 1937 (Sept. 12, 1936).

Furnace electrode clamp. W. H. Payne. Can. 364,538, March 2, 1937 (Nov. 16, 1936). G.M.H.

Grinding mill discharge. S. L. Miller and G. T. Johnson (American Ball-Mill Co.). Can. 365,362, April 13, 1937 (April 15, 1936; in U. S., Sept. 9, 1935). G.M.H.

Grinding mill end liner. S. L. Miller (American Ball-Mill Co.). Can. 365,841, May 4, 1937 (April 15, 1936; in U. S., Sept. 9, 1935). G.M.H.

Impregnation of articles by centrifugal means. W. A. Hyde (Leon J. Barrett). U. S. 20,444, July 13, 1937 (Dec. 9, 1935); reissue of original 1,981,453, Nov. 20, 1934.

Pulverulent material conveying apparatus. Mikael Vogel-Jorgensen (F. L. Smidth & Co.). Can. 366,339, May 25, 1937 (Dec. 16, 1935). G.M.H.

Resolution of suspensions of finely divided solids into substantially uniform solids fractions of varying average particle size. S. C. Lyons (Bird Machine Co.). U. S. 2,085,538, June 29, 1937 (July 10, 1936). A method of resolving an aqueous clay suspension containing sand, mica, and other relatively coarse impurities into separate substantially uniform solids fractions of different particle size comprises subjecting such suspension to repeated centrifugation under progressively intensified solids-depositing conditions as suspension proceeds from one centrifugating stage to the next, maintaining the solids depositing conditions, including the rate of flow of suspension, substantially constant in each stage, progressively removing during centrifugation each of the solids fractions and separately removing liquid effluent from the sphere of action of each of the centrifugating stages so as to maintain the effective centrifugating force in each stage substantially constant, subjecting liquid effluent from one centrifugating stage to the next, thereby effecting a removal from suspension of a substantially uniform solids fraction in each stage but of progressively increasing fineness as liquid effluent proceeds from one centrifugating stage to the next, and controlling the first centrifugation to remove from the suspension sand, mica, and other relatively coarse impurities.

Rotary kiln. R. C. Newhouse (Allis-Chalmers Mfg. Co.). Can. 364,932, March 23, 1937 (July 17, 1936). Mikael Vogel-Jorgensen (F. L. Smidth & Co.). Can. 366,529, June 1, 1937 (June 24, 1936). G.M.H.

Sieve. Roy Neher (National Gypsum Co.). Can. 365,537, April 20, 1937 (July 19, 1936). G.M.H.

Tube mill device. A. P. Dieschle (Diescher Tube Mills, Inc.). Can. 365,371, April 13, 1937 (Nov. 1, 1935). G.M.H.

Vibrating screen. G. A. Overstrom. Can. 365,591, April 20, 1937 (Jan. 21, 1936). G.M.H.

Viscosimeter. J. N. Goodier (Ontario Research Foundation). Can. 366,517 and 366,518, June 1, 1937 (Jan. 7, 1937; in U. S., May 25, 1936). G.M.H.

Kilns, Furnaces, Fuels, and Combustion

Application of electric heat in industry and crafts. H. Masukowitz. *Elektrowärme*, **7** [5] 91–100 (1937).—A comprehensive review is given of the modern application of electric heating in furnaces, etc. The widest use at present is made in the melting of ores and metals, heat-treating, hardening and joining of metals, drying and varnishing, and firing in ceramic processes. Melting of glass electrically is not yet generally applied. Constructive details of furnaces for the different purposes are described. M.H.

Developments in combustion control equipment. M. H. Mawhinney. *Ind. Heating*, **4** [1] 35–36; [2] 93–98; [3] 199–204; [4] 273–76, 282; [5] 370–74, 384; [6] 443–46 (1937).—A comprehensive review explains principles, methods and equipment for combustion with different fuels, and control of fuel consumption and of furnace atmospheres. M.H.

Electrically heated tubular furnaces with heat recuperation. K. Mertens. *Elektrowärme*, **6** [6] 184–87 (1936); abstracted in *Electrician*, **118** [3066] 324 (1937).—Interesting results have recently been obtained in a new type of electrically-heated conveyer tube kiln for firing mosaic floor tile. In the kiln, difference in temperature can be kept within narrow limits by the use of a series of tubes or heating chambers merely a few inches in height, arranged one above another. By this method the charge presents a large surface to the heat per unit weight. The experimental kiln is 20 ft. long with a 5-ft. firing zone between two equalizing zones 7 ft. 6 in. each in length. The ware is placed on refractory carrying plates which are pushed through the tube by mechanical means, the direction of travel in the individual tubes being in opposite directions so that the heat of the outgoing material is transferred to the incoming charge. The working temperature of the central zone was 1270°C; at this temperature it was possible to fire white tile satisfactorily which, in a solid-fuel kiln, would have necessitated a considerably higher temperature outside the saggers. The average temperature of the outgoing ware was 100°C, and it was found that, on account of the small height of the tile when loaded in this manner, the normal firing time of 10 hr. in a round or tunnel kiln could be reduced to a period which varied from 1 to 3 hr. Although it was hardly thought probable that favorable consumption figures would be obtained in an experimental kiln, the results were considerably more interesting than had been expected. In normal working conditions, kilns with 30 to 60 tubes would be used, and with the reduction of exterior kiln surface to tube capacity it is estimated that the furnace losses per ton of material heated would be decreased 25 or 33½%; it is hoped eventually for normal working conditions to reach a consumption figure of 120 to 150 kw.-hr. per ton of tile fired. When the foregoing points are considered in conjunction with the advantages offered in reducing the total length of the firing process to about one tenth of that originally required by solid-fuel kilns, a similar reduction in floor space occupied, and an absolute control of temperature and furnace conditions, upon which the success of the process mainly depends, it will be seen that this type of kiln presents possibilities both for the ceramic industry and the electricity supply undertakings in whose area such works are situated. H.K.R. + M.H.

Indian coals, with special reference to their coking properties. K. Bunte, H. Bruckner, and J. Sanjana. *Tisco Rev.* [India], **4** [9] 726–29; [10] 800–803; [11] 877–81; [12] 955–57 (1936). A.P.S.

Manufacture of salt-glazed stoneware pipes and fittings. A. Coulhon. Translated in *Brit. Clayworker*, **46** [541] 40–42; [542] 73–75 (1937).—C. discusses the distribution of kiln gases and the salting of the ware in a tunnel kiln. A general summary is given of the construction and maintenance of kilns in general and some hints on the proper

setting of ware in a kiln. The changes taking place in the fuel during combustion in the kiln are described in detail. See *Ceram. Abs.*, **16** [7] 216 (1937). R.A.H.

Possibilities of gas fuel in the nonferrous metal industries. J. E. WHITE. *Metal Ind.* [London], **48** [5] 167–69 (1936).—The outstanding advantages of town's gas as an industrial fuel are (1) uniform quality, (2) lower maintenance costs, (3) ease of measurement of fuel which makes cost accounting more accurate and easier, (4) less capital outlay due to simplicity of equipment and design, and (5) high temperatures that do not require tall chimneys which are costly to build. The possible uses are melting and extrusion of nonferrous metals and rolling and annealing operations. H.E.S.

Primer on combustion. ANON. *Ceram. Ind.*, **26** [4] 292–94; [5] 374–76 (1936).—The three methods of heat transfer, conduction, convection, and radiation, are discussed, and methods used in various ceramic processes are given. Causes of heat losses, their reduction by proper insulation, and methods of recovering heat are cited. E.J.V.

Problems in firing industrial kilns. ELLSWORTH P. OGDEN. *Brit. Clayworker*, **46** [541] 48–51 (1937).—O. discusses the firing of industrial kilns for firing paving brick, fireclay brick, and clay fireproofing shapes. R.A.H.

Transmission of heat through metal walls. R. E. LIGHT. *Power & Works Engr.*, **32**, 108–12 (1937).—L. gives a comprehensive review, with tables and charts for establishing correct heat transfer values. F.P.P.

BOOK

Keystone Coal Buyers Manual (1935). Edited by SYDNEY A. HALE. McGraw-Hill Book Co., Inc., New York. 458 pp. Price $10.00. Reviewed in *Power*, **79** [10] 557 (1935). F.G.H.

PATENTS

Muffle flue. C. W. SAXE (Norton Co.). U. S. 2,087,215, July 13, 1937 (March 10, 1936).

Tunnel kiln. C. H. PARMELEE (Onondaga Pottery Co.). Can. 366,515, June 1, 1937 (April 23, 1936). Can. 366,516, June 1, 1937 (April 18, 1936). G.M.H.

Geology

Ampthill clay. ANON. *Geol. Survey Gt. Brit., Summary of Progress*, Part II, pp. 60–86 (1935). H. M. Stationery Office, London, 1937. Price 3s net. A brief description of the Ampthill clay and other Corallian clays near Cambridge, England, and a detailed report on the ammonites therein are given. The clay is used for brickmaking. A.B.S.

Bentonites of the Dniester region. C. I. NAZAREVICH. *Geol. Zhur.*, **3** [2] 215–23 (1936).—The results of preliminary study of sandy bentonite deposits found in the Dniester region are discussed. These bentonites are chiefly represented by montmorillonite. M.V.C.

Beryl and ceramics. DANIEL W. LUKS. *Foote-Prints*, **10**, 1–11 (1937).—The general background of the mineral, beryl, is reviewed. Formulas for its introduction into glazes and porcelain bodies are quoted with corresponding values for maturing ranges, thermal expansion and conductivity, specific electrical resistance, and strength. A.P.

China clay. ANON. *Trade & Eng.*, **41** [880] xii (1937).—A brief description of the material and methods of production is given. For every ton of china clay produced in Cornwall, seven tons of overburden, rock, and sand must be tipped and 100 tons of water employed. The valuable aid given by chemical and physical tests in suggesting the suitability of the clay for various purposes is emphasized. Colloidal kaolin, prepared from china clay, is now used in numerous industries, especially in finishing delicate leathers, soap manufacture, paints, cosmetics, dentifrices, and many pharmaceutical products. The output from Cornwall is steadily increasing; in 1936 it was 750,000 tons. A.B.S.

Cristobalite at Crater Lake, Oregon. CARL E. DUTTON. *Amer. Mineralogist*, **22** [6] 804–806 (1937).—Octahedral crystals of cristobalite, varying in size from microscopic dimensions to slightly greater than 1 mm., have been found in Crater Lake National Park. F.J.Z.

Crystal structure of alunite and the jarosites. STERLING B. HENDRICKS. *Amer. Mineralogist*, **22** [6] 773–84 (1937).—X-ray diffraction data have been obtained from alunite, jarosite, natro-, argento-, ammonio- and plumbojarosites, karphosiderite, borgströmite, hamlinite, and the compound $3Fe_2O_3 \cdot 4SO_3 \cdot 9H_2O$. The crystal structure of the alunite-jarosite group of minerals is derived from these data, and an explanation is advanced for the various types of isomorphous replacements shown by the group. The structures are characterized by binding between hydroxyl groups and an oxygen atom of a sulfate group. F.J.Z.

Diatomaceous earth. KENNETH TOMLINSON. *Discovery*, **18**, 85–86 (March, 1937).—The origin and uses of skeletal silica are described. Hitherto England has had to import from Germany or the U.S., but an extensive deposit found at Kentmere in the Lake District promises to fill the home demand. H.H.S.

Dilatometer method for determining the moisture equivalent of soils. G. J. BOUYOUCOS. *Soil Sci.*, **43** [5] 385–89 (1937).—The dilatometer method possesses the following advantages: (*a*) it is comparatively free from the influence of external factors and is consequently less empirical, and the results are on a more nearly absolute basis; (*b*) it makes two important determinations at the same time (moisture equivalent and wilting point); (*c*) it is rapid and simple; and (*d*) the apparatus required is simple and inexpensive. G.R.S.

Identification of certain gem-stone materials by their emission spectra. DAVID H. HOWELL. *Amer. Mineralogist*, **22** [6] 796–802 (1937).—A technique is described whereby material sufficient for emission spectroscopy may be obtained without serious damage to valuable specimens. The method has been found satisfactory in distinguishing between the various species of garnet, spinel, jadeite, sillimanite, andalusite, etc. The procedure is considered to be applicable generally in distinguishing between species which have similar optical and physical properties but different chemical compositions. F.J.Z.

Kaolins of Allier and Nièvre, France. V. CHARRIN.

Ceram., Verrerie, Email., **4** [5] 183–84 (1936).—Although the two richest kaolin deposits are in Haute-Vienne, there are other deposits in Nièvre and Allier which are considered secondary, not in quality but in extent. In Nièvre the deposits fall into the class of interstratified deposits in sedimentary rock. The sand bed containing the kaolin is from 2 to 4 m. deep with a kaolin content of 15 to 25%. The kaolin of Allier belongs to the other class of deposits in which the kaolin is in or near the matrix rock. Their chemical analysis is silica 49.76, alumina 36.69, iron oxide 0.84, lime 0.14, magnesia 0.10, potassium 0.81, soda, 0.62, and H_2O 10.96%. M.V.C.

Laws of soil colloidal behavior: XVIII, Colloidal electrolytes. SANTE MATTSON AND YNGVE GUSTAFSSON. *Soil Sci.*, **43** [6] 421–52 (1937).—The theory of the interaction of colloidal hydroxides with colloidal and soluble acids is discussed, and two forms of isoelectric precipitates are accounted for. By determining the ultimate p_H and the titration curves of electrodialyzed samples, when single and when mixed, it is shown that soils having different isoelectric points (or p_H of exchange neutrality) interact in a general way according to the theory of ampholytes. In the case of amphoteric colloids, however, the mutual neutralization proceeds further because of the limited dissociation of their salts. The chemistry of exchange acidity, exchange alkalinity, and of the point of exchange neutrality is expounded. The reactions of the soil colloidal complex are fundamentally the same as those of ordinary weak electrolytes and can be accounted for by a special application of the known laws of ordinary weak acids and bases and of ampholytes. 11 references. **XIX, The gel and the sol complex in soil formation.** *Ibid.*, pp. 543–71.—The ionic and cationic sol complexes, obtained at different hydrogen ion concentrations in the extracts from various mixtures of soil and humus, were studied with respect to composition and isoelectric point. It was found that there is a minimum of solvation at a p_H which corresponds to the isoelectric point of the gel complex in the mixture. Above this p_H, the sol complex is anionic and more acidic than the gel complex, whereas it is cationic and more basic than the latter at a lower p_H. Applied to the process of soil formation, a distinction is made between anionic solvation and eluviation, leading to laterites and red and brown earths, and cationic solvation and eluviation, leading to podzolic soils. 15 references. For Parts **XVI–XVII** see *Ceram. Abs.*, **15** [3] 108 (1936). G.R.S.

Method for improving the physical properties of clays. J. W. WHITTEMORE AND F. W. BULL. *Jour. Amer. Ceram. Soc.*, **20** [8] 261–65 (1937).

Mineral deposits of eastern Singhbhum and surrounding areas. J. A. DUNN. *Mem. Geol. Survey India*, **69** [1] 1–279 (1937).—D. describes the economic mineral deposits in eastern Singhbhum, one of India's richest mineral provinces, and the immediately surrounding areas, together with a summary of the general geology to elucidate the genetic relations between the several deposits and to indicate the origins of the country rocks with which the deposits are associated. The mineral deposits described are the copper and related deposits (copper, apatite-magnetite, gold, wolframite, mica, and lead veins), iron ores and related deposits (iron ores, vanadium ore, manganese, and chromite), and other deposits (asbestos, barytes, clays, garnets, ochers, platinum, refractory materials, talc, and slate). Most of these minerals are being mined today. Illustrated. A.P.S.

Origin of the bedding replacement deposits of fluorspar in the Illinois field. L. W. CURRIER. *Econ. Geol.*, **32** [3] 364–86 (1937).—The banded fluorspar deposits of the Cave In Rock district are attributed to replacement of limestone and the preservation of bedding and cross-bedding of the rock. Chemistry and controlling conditions are discussed. 10 figures. J.L.G.

Pennsylvania glass sand industry in 1936. R. W. STONE. *Bull. Amer. Ceram. Soc.*, **16** [7] 288–91 (1937).

Radium and ceramics. V. CHARRIN. *Céram., Verrerie, Email.*, **4** [3] 99–100 (1936).—The uranium ceramic pigments, autunite ($CaO{\cdot}2UO_3{\cdot}P_2O_5$), which has a yellow green tint, and chalcolite ($CuO{\cdot}2UO_3{\cdot}P_2O_5$), which has an emerald green color, are secondary minerals derived from pitchblende which is a source of radium. Deposits of uranium minerals in France are cited. M.V.C.

Rare earths for ceramic purposes. ANON. *Keram. Rundschau*, **44** [28] 329 (1936).—Cerite carbonate or cerite oxalate are wastes of variable composition. The opacifying effect is due exclusively to cerium oxide. The remainder (50 to 60%) is a mixture of rare earths of disputable effect on glazes. The refractoriness is inferior to that of tin oxide. Cerium oxide gives bubbles in enamels. Didymium causes yellow discoloration. F.E.V.

Secondary deposits of bauxite in France. V. CHARRIN. *Rev. Matériaux Construction Trav. Publics*, No. 330, pp. 63–67 (1937).—The secondary deposits of bauxite are isolated and much less extensive than the great beds which make France one of the first in bauxite production, and as yet they have no industrial importance though they will eventually have to be drawn upon. They are located in the departments of Var and Bouches-du-Rhône, Hérault, and the Pyrénées-Orientales. See "Peculiar—," *Ceram. Abs.*, **16** [7] 220 (1937). M.V.C.

Secondary deposits of kaolin in France. V. CHARRIN. *Céram., Verrerie, Email.*, **4** [2] 53–54 (1936).—Besides the great kaolin deposits of Brittany, Limousin, Allier, and Nièvre, there are secondary deposits in the Dept. of Manche, the Eyzies region, and the Pyrenees, which are worked only intermittently. These deposits are described. M.V.C.

Significance of particle size within the clay fraction. R. H. BRAY. *Jour. Amer. Ceram. Soc.*, **20** [8] 257–61 (1937).

Tolkachevskiĭ quartzites as raw material for silica brick. K. A. ZHUKOVSKIĬ. *Geol. Zhur.*, **3** [3–4] 110–22 (1937).—A detailed geological description of the Tolkachevskiĭ quartzite deposits is given. A preliminary study of mineralogical and chemical composition and of the technological properties of these quartzites show that they are a valuable raw material for the manufacture of silica brick. M.V.C.

Vanadium-bearing titaniferous iron ores in Singhbhum and Mayurbhanj, India. J. A. DUNN AND A. K. DEY. *Trans. Mining & Geol. Inst. India*, **31** [3] 117–84 (1937).—Vanadium-bearing titaniferous ores have been found in southern Singhbhum and northern Mayurbhanj with V_2O_3 content varying from 0.6 to 6.0% but very irregularly distributed. A description of the Indian deposits,

uses, occurrences in nature, world's resources, and treatment of V and Ti ores is presented. These ores, however, contain the highest percentage of V_2O_5 yet known in such magnetic ores. The future value of high-grade vanadium-bearing titaniferous magnetites depends upon the determination of a suitable method of extraction of either the vanadium or the titanium or both. A.P.S.

X-ray investigation of the pyrochemical changes in Missouri halloysite. FRANK J. ZVANUT AND LYMAN J. WOOD. *Jour. Amer. Ceram. Soc.*, **20** [8] 251–57 (1937).

BOOKS AND REPORTS

Bauxite industry in 1936. ANON. *U. S. Bur. Mines Mineral Markets Rept.*, MMS 540, 2 pp. Free. An advance summary of this industry is presented. R.A.H.

Introduction to the Study of Minerals. AUSTIN FLINT ROGERS. McGraw-Hill Book Co., New York. $5.50, postpaid. Reviewed in *Can. Mining Jour.*, **58** [6] 320 (1937). G.M.H.

Magnesite industry in 1936. ANON. *U. S. Bur. Mines Mineral Markets Rept.*, MMS 535, 3 pp. Free. An advance summary of the industry is presented. R.A.H.

Mining and milling methods and costs at the glass-sand plant of P. J. Weisel, Inc., Corona, Calif. EDMUND SHAW. *U. S. Bur. Mines Information Circ.*, No. 6937, 16 pp. Free. R.A.H.

Ores and Industry in South America. H. FOSTER BAIN AND THOMAS THORNTON READ. Harper & Brothers, New York. 381 pp. Price $3.50. Reviewed in *Foundry*, **63** [3] 67 (1935).—The mineral wealth of South America is described and discussed. F.G.H.

Report of work of the Mining Division, U. S. Bureau of Mines, for the year 1936, and program for 1937. CHAS. F. JACKSON. *U. S. Bur. Mines Information Circ.*, No. 6939, 16 pp. Free. The work of seven sections of the Mining Division is outlined, and the publications issued are listed. R.A.H.

PATENT

Mineral pulping apparatus. J. M. MCCLAVE. Can. 365,440, April 20, 1937 (June 1, 1935). G.M.H.

Chemistry and Physics

Absorption-reflection spectra of the chrome colors. A. G. GAYDON. *Trans. Ceram. Soc.*, **36** [2] 49–55 (1937).—Quantitative measurements of the spectra of the light scattered from the surfaces of seven tile glazed with the chrome colors green, brown, emerald-green, yellow, coral-red, chrome-tin crimson, and chrome-tin pink, using light scattered from the white back of one tile as a comparison spectrum, have been made in connection with work on the chemistry of the chrome-tin colors (see following abstracts). The method of obtaining the spectra is described, and absorption curves for the tile reproduced from photographs of the spectra taken through a neutral tint wedge are shown. R.H.H.P., JR.

Arrangement for obtaining diffraction diagrams of intensely crystalline powders with a monochromatic radiation. A. GUINIER. *Compt. Rend.*, **204** [15] 1115–16 (1937).—An apparatus is described by means of which monochromatic X-rays can be obtained with a cylindrically surfaced crystal; the radius of the curvature was 48 and 96 mm. in the experiments. The exposure for obtaining clear diffraction diagrams, with an X-ray tube of 32 kv. and 30 milliamperes, was 2 min. for a Ni foil and 15 min. for vitreous silica. M.H.

Chemistry of chrome-tin colors. J. W. MELLOR. *Trans. Ceram. Soc.*, **36** [1] 16–27 (1937).—To determine the nature of the chrome-tin pink or crimson colors, absorption reflection spectra of the chrome colors green, brown, emerald-green, yellow, coral-red, chrome-tin crimson, and chrome-tin pink were measured and compared. Chromic oxide and stannic oxide present in a glaze in the proportion of 1:5 produce a green color; a ratio of 1:17 to 20 gives red, and 1:25, pink. Finely divided chromic oxide is red, not green, and the stannic oxide in the glaze acts essentially as a chemically inert mordant for the aërosol of chromic oxide. The chrome-tin pink stain is really a deposit of highly dispersed chromic oxide condensed from the vapor state on stannic oxide, and the amount of chromic oxide and the average size of the colloidal particles determine variations in tint. Triangular color charts of mixtures fired at cone 10 in the system SnO_2–CaO–SiO_2 plus 3% potassium dichromate show the effect of silica and whiting, which favors the dispersion of the colloidal red oxide on stannic oxide. In general, the greater the proportion of lime in the stain up to 25%, the better is the color, but higher proportions tend to make the tint paler by dilution. The composition of the glaze has an important effect on the stability of chrome-tin colors, and additions of calcium fluoride, chloride, and sulfate help to protect the colors from attack by the glaze. R.H.H.P., JR.

Cobalt and nickel colors. J. W. MELLOR. *Trans. Ceram. Soc.*, **36** [1] 1–9 (1937).—Of the green, pink, purple, and blue colors that result from the use of cobalt oxide as a tinctorial agent, the simple cobalt blues are the most important and can be arranged in two classes: (1) cobalt silicate blues characterized by ultramarine blue and obtained by firing at high temperatures mixtures of cobalt oxide and flint or cornish stone, and (2) mat blues or cobalt aluminate blues derived from calcined mixtures of cobalt oxide and alumina. A typical mat blue contains cobalt oxide 20 parts, zinc oxide 20, and alumina 60; triangular color diagrams are shown of mixtures of the three oxides calcined and ground, under a lead glaze, and under a leadless glaze. The mat blue colors are, in general, unstable in contact with the glazes, especially at the higher temperatures and with longer periods of firing, and tend to revert to ultramarine blue as the equilibrium tint. Glazes rich in lead and boric oxide attack the mat blues rapidly; glazes high in alumina and low in lead are less severe in their action and hence furnish the best colors. Thénard's blue is made from alumina and cobalt oxide with or without zinc oxide. A solid solution of the two oxides produces Rinman's green, and when magnesia replaces the zinc oxide, a cobalt-magnesium pink or purple color is formed called Berzelius' pink. The Chinese or Mohammedan blues range from clear sky blue to grayish blue,

and the richer tones are attributed to the effect of impurities in the cobalt oxide which are now removed by modern refining. Mechanical mixing does not produce similar tones, and chemical mixing merely approximates them. The colors of the system NiO–ZnO–Al_2O_3 have also been investigated and are reported to be unstable and unreliable. Color plates are given of triangular diagrams in which mixtures of the three oxides are calcined and ground, under a lead glaze, and under a leadless glaze.

R.H.H.P., Jr.

Collation of experimental data: 39. A. Alison. *Glass*, **13** [12] 504 (1936).—Methods of collecting, interpreting, and expressing experimental data, particularly when a great many observations and sets of data are involved, are presented. **40.** *Ibid.*, **14** [1] 10 (1937).—The determination, significance, and adaptation of the correlation coefficient as related to experimental data are given. **41.** *Ibid.*, [2] 49.—A. discusses the computation and adaptation of index numbers for expressing experimental data. For Parts **36-38** see *Ceram. Abs.*, **16** [3] 86 (1937).

M.C.S.

Crystal and the engineer. W. H. Bragg. *Iron & Coal Trades Rev.*, **134** [3610] 843 (1937).—The structure of the crystal is considered from the engineering standpoint, the knowledge of which makes it possible to find out the strength of a given design; the arrangement of the atoms and the play of the forces both within the substance and on the surface determine the characteristic qualities of the substance. The principle of using X-rays instead of ordinary light rays for determining the structure and of the use of electron-diffraction methods for information on surface conditions is explained. The "structure-sensitive" properties of metals and other materials are important for all structural work and can be influenced by heat treatment, forging, and alloying to obtain a desired result.

M.H.

Determination of phosphoric anhydride in phosphate rock, superphosphate, and "metaphosphate." James I. Hoffman and G. E. F. Lundell. *Jour. Research Nat. Bur. Standards*, **19** [1] 59–64 (1937); R.P. 1010. Price 5¢.—A gravimetric method requiring no molybdate reagent is described for the determination of phosphoric anhydride in phosphate rock and similar materials. R.A.H.

Discoloration of chrome-green colors. J. W. Mellor. *Trans. Ceram. Soc.*, **36** [1] 28–30 (1937).—Earthenware prepared with underglaze chrome greens by the same processes sometimes comes from the glost oven with greens variable in tint. Experimental evidence shows that the richest greens are produced under reducing conditions and that the presence of small amounts of stannic or zinc oxide often increases the discoloration of the greens with variations in temperature. The amount of boric oxide should always be less than that of alumina in the glaze or the proportion of lime should be high. Unstable chromates are sometimes formed in the glost oven in an oxidizing fire in the presence of highly basic oxides and may also cause discoloration. R.H.H.P., Jr.

Ferric oxide colors. J. W. Mellor. *Trans. Ceram. Soc.*, **36** [1] 31–43 (1937).—The colors which can be produced by ferric oxide dissolved in a glaze range from red through violet; the green and blue are developed in a reducing atmosphere. About 5 to 7% of ferric oxide dissolves in a glaze at ordinary temperatures to form a complex ferric lead silicate of a transparent yellow color. At higher temperatures, glazes dissolve more ferric oxide and, if slowly cooled, produce beautiful aventurine effects with spangles of hematite crystals. Colors produced by ferric oxide suspended in the glaze depend upon the color impressed on the ferric oxide during its preparation. A range of tints from orange-red through violet-red can be obtained with increasing temperature of calcination, while additions of manganese give the deeper tints to iron-gray. These tints, Pannetier's iron colors, are illustrated in color. The colors obtained by calcining ferrous sulfate over the range 600 to 900°C have all been analyzed with Lovibond's standard tintometer. In studying the effect of the grain size of the iron oxide particles on color, it was found that the finest particles are yellow while coarser particles are red. Reflection spectra and formulas are given for underglaze black and brown. A description is included of the natural ferric oxide colors, both hydrated and anhydrous. R.H.H.P., Jr.

Heat capacity of combined water and of soils. P. I. Andrianow. *Kolloid-Z.*, **78** [1] 107–108 (1937).—Investigation of silica sand, clay, humus, peat, and mixtures thereof showed the heat capacity of the combined water in several soils to average less than 1 (0.70 to 0.75). Calculation of the corresponding values for several chemical compounds also gave figures smaller than unity (0.4 to 0.8). F.P.P.

Investigation of sodium aluminate. A. Maffei. *Gazz. Chim. Ital.*, **65**, 108–16 (1935).—M. describes a hydrolyzation process in which pure sodium aluminate solutions without excess of soda can be obtained. M.H.

Linear mineralogical arithmetic. A. L. Parsons. *Amer. Mineralogist*, **20**, 388–92 (1935).—Graphic methods of determining molecular proportions with a high degree of accuracy and the calculation of the mineral percentages in rocks from the chemical analyses and specific gravities are presented. F.J.Z.

Polymorphic transitions of inorganic compounds to 50,000 kg./cm.² P. W. Bridgman. *Proc. Nat. Acad. Sci.*, **23** [4] 202–205 (1937).—In applying pressures to 50,000 kg./cm.², B. has found 35 inorganic compounds that exhibit polymorphism in this pressure range. More than 50 other compounds were examined with negative results. The transition parameters (pressure, temperature, change of volume, and latent heat) for these transitions are tabulated for 20 substances. Temperature range of the measurements was from −79°C to +200°C. Average temperature referred to in the table was 100°C. The 15 substances not tabulated are named, and the reasons for omitting them are mentioned (sluggish inversion, wide variation of parameters, more than one inversion, etc.). Statistical trends of the results are discussed.

J.L.G.

Progress of science. R. A. Millikan. *Sci. Monthly*, **42**, 87–88 (1936).—The award of the Nobel prize in physics has been made to James Chadwick for the exceedingly important discovery of the neutron. The heart or nucleus of the atom is revealed, and through these discoveries it is becoming evident how some of the heavier atoms are being built up out of hydrogen. With their aid more than seventy definite cases of the "transmutation

of the elements" have been produced. The Nobel prize in chemistry has been awarded to the Joliots for their discovery of artificial radioactivity which has been produced in several different ways and with many different working substances. Until this work was done, the phenomenon of radioactivity was believed to be completely beyond the control of man. H.E.S.

Rapid method for determining lime and magnesia. HORNKE. *Tonind.-Ztg.*, **61** [28] 311–12 (1937).—Experiments on a method for a rapid determination of lime and magnesia are described. The determination of lime, by the titration of calcium oxalate in a solution combined with sulfuric acid, with permanganate yields exact values when the solution to be investigated is heated to 70°. The presence of a paper filter is harmless. The precipitation of magnesium as magnesium-ammonium-phosphate in the boiling solution and subsequent stirring yield excellent results. Titration of phosphoric acid produces exact values when hydrochloric acid is used whose surplus can be determined by titrating back with soda lye. M.V.C.

Structure of solid bodies. E. WIGNER. *Sci. Monthly*, **42**, 40–46 (1936).—The progress in the explanation of the properties of solid bodies is due, on the theoretical side, to the newly developed quantum mechanics and, experimentally, mainly to the study of the crystal structure by X-rays. Without these tools these problems would be as unsolved as the problem of liquids where X-ray studies have proved less efficient. H.E.S.

Study of borates and oxides in the far infra-red. M. PARODI. *Compt. Rend.*, **204** [15] 1111–12 (1937).—Transmission and reflection bands were studied in borates of Ca, K, Mn, Cu, and Pb and in some oxides; they showed that three distinct groups of different wave-length occurring in the infra-red region could be distinguished. They lie around 30, 40, and 52 microns. M.H.

Thermal decomposition of ammonia-permutite, ammonia-bentonite, and ammonia-clay. O. BOTTINI. *Kolloid-Z.*, **78** [1] 68–71 (1937).—Ammonia complexes were prepared from Na permutite, Ca bentonite, and Hessian pottery clay, and the loss on heating at 700°C was determined. Thermal decomposition was also observed at 50° intervals between 50 and 550°C. The stability of the adsorbed ammonia complex was different for the three materials and was variously affected by the temperature of heating. The ammonia-permutite complex was completely broken at 300°C, the ammonia-bentonite at 550°C, and the ammonia-clay at 500°C. The plot of ammonia loss *vs.* temperature was a straight line only for the ammonia-permutite. B. ascribes the different behavior of the three complexes to the structural differences inherent in the basic materials. F.P.P.

Thorium separation from rare earths; use of hexamine and its application to the determination of thorium in monazite sand. A. M. ISMAIL AND H. F. HARWOOD. *Analyst*, **62** [732] 185–91 (1937).—Hexamine precipitates quantitatively the hydroxides of Fe''', Al, Cr, Ti, U, Zr, and Th. Th can be separated quantitatively from Ce and other rare earths by using hexamine as precipitant. The application of the method to the determination of Th in monazite sand is described. H.H.S.

BOOKS

March of Science, 1931–1935. BRITISH ASSN. Isaac Pitman & Sons, London, 1937. 215 pp. Price 3s 6d. This is the first of a projected series of 5-yearly surveys of scientific progress by leading scientists. Contributors to the present volume include James Jeans, F. G. Hopkins, and Wm. Dunne. H.H.STEPHENSON

Terminology of Physics. C. G. DARWIN. Clarendon Press, Oxford, 1937. Price 2s 6d. Reviewed in *Notes & Queries*, **172** [9] 145 (1937). H.H.S.

PATENTS

Composition for combating foam. WERNER STEIBELT (I. G. Farbenindustrie A.-G.). U. S. 2,085,709, June 29, 1937 (July 5, 1932). A composition for reducing or preventing foam comprises a liquid mixture of a solid aliphatic alcohol containing more than 12 carbon atoms per mol. and a liquid aliphatic alcohol containing at least 8 carbon atoms per mol.

Treatment of silicate ores, etc. CAMILLE DEGUIDE (Soc. Recherches et d'Applications Chimiques (Sorac), Soc. Anon.). U. S. 2,084,630, June 22, 1937 (Aug. 8, 1936). A process of treating a silicate ore containing silica and oxide of zirconium comprises the steps of calcining the ore in the presence of a barium compound so as to produce dibarium silicate and barium metazirconate while avoiding fusing of the mass, treating the product obtained to form sodium silicate in solution, with barium metazirconate and barium carbonate as a residue, and calcining the latter to convert the barium metazirconate into barium orthozirconate.

General

Armco personal relations. HUGH W. WRIGHT. *Factory Management & Maintenance*, **95** [5] S-381–92 (1937).—W. describes the system of personnel treatment which has prevented the American Rolling Mill Co. from losing production and the employees from losing wages due to labor disputes in the entire history of the company's operation (36 years). Topics treated are (1) organization and policies, (2) employment, (3) medical department, (4) safety and training, (5) fair wage plan, (6) the Armco association, (7) credit unions, (8) group insurance, (9) organization publicity, (10) community relations, and (11) employee representation. J.L.G.

De-airing of boiler feed water. R. W. BRUNNER. *Jour. Amer. Soc. Naval Engrs.*, **49** [5] 127–52 (1937).—A clear, concise outline of the corrosion theory shows the part O_2 plays in depolarization and in increasing the surface exposed by roughening due to oxide formation. Due to increased pressures and ratings for Naval boilers with lower weight factors, the structures are more vulnerable and therefore require increased attention toward a lower corrosion rate. A simple calculation is made to show that a modern destroyer at 15 knots cruising rate with 0.4 ml. O_2/liter, as measured recently on board ship, would corrode over $^1/_2$ lb. of Fe from boilers and tubes in 24 hr. Reduction of dissolved O_2 by de-airing is considered the answer to the problem, and various systems of de-airing

are discussed and illustrated in sketches and diagrams. The method of testing for dissolved O_2 in use by the Navy is the modified Winkler test, the only one available at present. Attention is being given to the spectrophotometer method which, with further development, may indicate critical limits. The modified Winkler test requires extreme precautions in sampling and in basing the determination on several simultaneous tests. Tests are tabulated for various parts of the feed-water system to indicate variations in O_2 content along the line ranging from 0.03 to 1.0 ml./liter, the present aim being to reduce this to a 0.10 ml./liter maximum. Chemical control of O_2 is not feasible due to the large amounts of chemicals that would be required in ships stores for the purpose. W.H.B.

Factors governing furnace size. R. B. PURDY. *Power*, **79** [9] 470–72 (1935).—A detailed discussion of the numerous factors involved is presented. Illustrated. F.G.H.

Functions of a research department. T. M. HERBERT. *Glass*, **12** [7] 292 (1935).—H. discusses his original presentation (*Ceram. Abs.*, **14** [10] 263 (1935)). The effectiveness of the individual laboratories is dependent to a great extent upon the coöperation between them. Reference is made to the American way of conducting research where there is a free exchange of ideas, information, and data between various laboratories and engineers. M.C.S.

Process research and the evolution of a new technique. R. S. HUTTON. *Metal Ind.* [London], **48** [3] 55–58 (1936).—To deal with the problem of stimulating and carrying out process research aimed at drastic innovations two conditions are obvious: (1) it can not be linked up with ordinary routine production, and (2) the work can not be easily executed in the ordinary research laboratory. Much can be learned from small-scale tests sometimes far removed from the actual location of manufacture. Works development departments and outside institutions are playing an important part in industrial progress. H.E.S.

Technology, the science of industrial arts. ANON. *Pottery & Glass Record*, **19** [6] 158 (1937).—The importance of technology in the manufacture of pottery is explained, and the reading of descriptive books on potters and pottery by salesmen (as well as by craftsmen) is advocated as an aid to increased selling power. A.B.S.

BOOKS

Ceramic Technology: Vol. I. P. P. BUDNIKOV. *Gosud. Nauchno-Tech. Izdat. Ukrainy, Kharkov*, 1937. 3rd ed. 521 pp. Price 8R 50k. A complete discussion of the history of ceramic raw materials, glazes, and ceramic pigments is presented. For Vol. II see *Ceram. Abs.*, **13** [4] 106 (1934). M.V.CONDOIDE

Industrial coal-burning equipment. ANON. *Appalachian Coals, Inc., Booklet*, 19 pp.; reviewed in *Power*, **79** [9] 501 (1935).—An analysis, covering 7284 plants, illustrates the comparative importance of various types of coal-burning equipment used by industrial plants in eight states. F.G.H.

Preparation of Engineering Reports. T. R. AGG AND W. L. FOSTER. McGraw-Hill Book Co., New York. 192 pp. Price $1.75. Reviewed in *Mech. Eng.*, **58** [2] 132 (1936).—The beginner in report writing will find this work a help in presenting his material in an orderly manner. The collection of the data, arrangement of the subject matter, style, illustrations, and other practical questions are systematically discussed. F.G.H.

PATENT

Roofing granule manufacture. E. H. NICHOLS. Can. 365,590, April 20, 1937 (Jan. 29, 1936). G.M.H.

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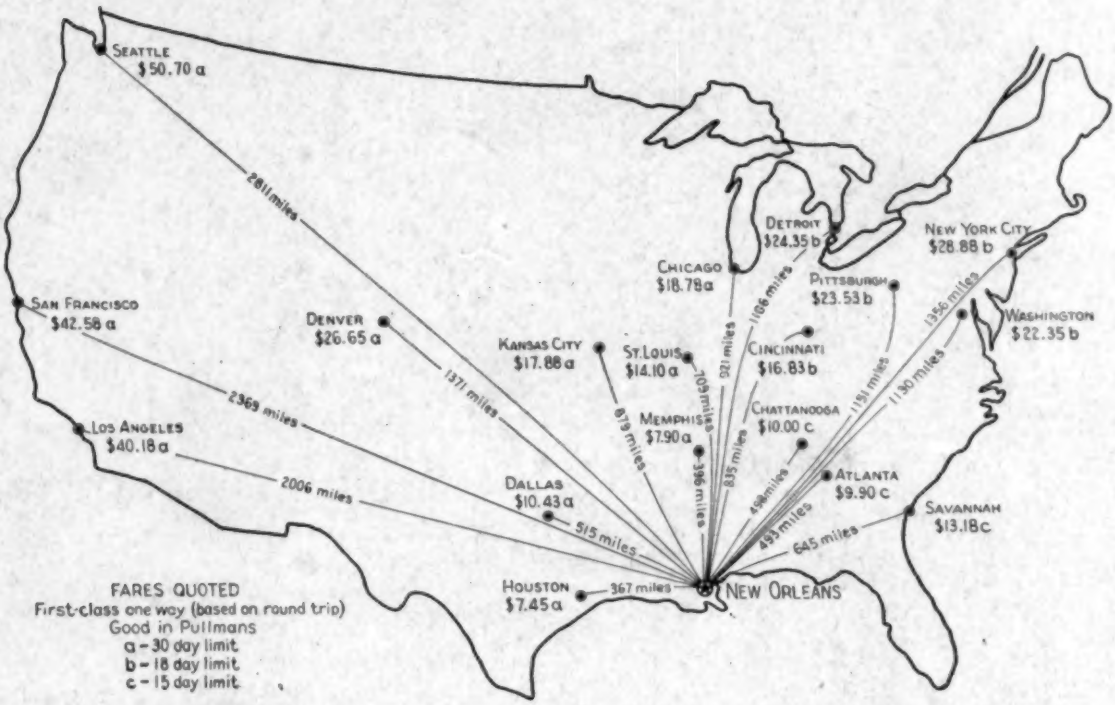

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